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Presidential Address

Some Aspects of Mechanical Advancement during the Life of the Society

By H. G. CAMPBELL, M.A., A.M.I.Mech.E., A.M.I.E.E. (*Fellow*)

It is with some diffidence, but a great deal of pride, that in this Jubilee Year of our great Society, I stand before you—the successor to a long line of eminent Presidents. Most of those who have been honoured in this way have been scientists, physicists, ophthalmologists or electrical engineers, and have all had a great deal of knowledge on the fundamentals of lighting generally. For a great many years, indeed, if at all, our Society has not honoured a man as its President who, by qualifications at least, can claim some knowledge of both mechanical and electrical engineering. It was for this reason that, as the title of my address indicates, I thought we might consider some of the mechanical advancement that has taken place during the past fifty years as opposed to the purely scientific and electrical engineering aspects of our interests.

The present is an era of Jubilees, of Golden Jubilees, and this is so because it is a time of golden fruition after fifty years of unprecedented development, progress and discovery. It is that measure of time since Louis Bleriot first flew the English Channel and so knocked on the door of our insular security. From the birth of the century and its earlier years came a most impressive procession of discoveries, inventions and achievements. We have had, during this time, the advent of the motor car, the radio, the aeroplane, television, electronics, and, less spectacularly perhaps, extraordinary advancement in medicine, in science and in practically everything that has improved the general mode of living and increased the expectancy of life.

But the industry of light leads back to the very morning of time when prehistoric man sought ways and means of producing light. It may perhaps be amusing to apply our minds for a moment to the relationship of the engineer to lighting. I suppose it would not be unreasonable to assume that early man, though he did not know it, was a combination of a civil, a mechanical and a chemical engineer. As a civil engineer, he dug in the earth for materials, and as a mechanical engineer he fashioned these into lamps. His chemical knowledge he applied in choosing the animal fats and the oils he used to burn, and in the choice of the vegetation for the wick. Our pioneer lighting engineer, when he moved out of his cave into more spacious dwellings, had to collaborate very early on with the architect to provide suitable niches—at proper spacing—to accommodate his ceramic lamps.

Research, experiment and the application of man's scientific achievements follow a line of relentless persistency; progress seems to be preordained. In our own industry, there is an amalgam of physicist, physiologist, ophthalmologist, architect, chemist, engineer and indeed a variety of scientists and constructionists, all pulling on different oars but propelling the same boat; a boat which can never reach the ultimate harbour because progress knows no end.

I have said that science or art, or the industry of light, dates back to the prehistoric, but antiquity is of less import than recent history. It is fair to say that until this present great, but hectic, century our forebears lived in a leisurely world; progress was slow but sure. It is as though the ship of discovery made its slow path through the doldrums for many centuries until the trade winds of this present one filled its sails and immeasurably increased the tempo of its progress. The winds increased so that our ship of progress sped rapidly on its voyage of discovery and it is still bending its masts on the unseeable, but imaginable, future. Ours, however, was not the only ship that sailed the unchartered seas and the enchanted waters. There were others that sought the Golden Fleece and reached their Golden Jubilees. The great fleet, composed of a multitude of ships, that cast anchor at the beginning of the century has, during its voyaging, entirely altered the social strata of the world.

The aeroplane has annihilated distance, so that today a trip around the world takes far less time than we could have travelled around Great Britain before its advent. The motor car has made the entire country a pleasure ground for its populace so that metaphorically speaking the waves lap at the front doors of inland cities and the mountains are their gardens. Electricity, and its adaptation to the mobility of light and sound, has established immediate communication. Through the media of television and the radio, the peoples of the world can see and hear what the rest of the world is doing, virtually whilst it is doing it.

Presented at a meeting of the Society held in London on October 13, 1959.

The amazing progress during the last fifty years to which I have referred, has been in spite of—perhaps I should say, because of—two global wars. War is a relentless, but not abnormal, phase of life ; but how terribly has it developed. War is a robber as well as a murderer, for it steals our enjoyment of life, it absorbs our natural wealth, and it causes dislocation in normal industry. The peacetime purse of the Treasury, however, whose contents were reluctantly used for the purpose of research, becomes a treasure house, spending lavishly on weapons of destruction. Necessity being the mother of invention, there is a prolific offspring in the laboratories. We acquire greater knowledge because the need for it is greater than in peacetime. Weapons, whether they be guns or aeroplanes or any other form of munition, are produced, which to be effective, must endure greater stresses and we meet that demand by adding, for instance, to our metallurgical and technical knowledge. War repays some debt, however ; it leaves us with a legacy of knowledge which serves us to produce better merchandise from better material and by better methods. We should never have attained our present efficiency in so short a time in manufacture if war had not given us this legacy of expedited experience and speed up in "know-how."

The year 1909 was, of course, a most significant one for us in that it was the year of our birth, and I think we may claim to have been born in one of the "vintage" years in history. It was a specious, leisurely year as compared with modern standards. It was, however, marred by probably the greatest disaster ever to have occurred—the Messina earthquake in Sicily with its death roll of 100,000 people.

King Edward VII reigned benignly over a generally satisfied, but perhaps too complacent a people. The unhurried public were not concerned to crowd the miles into the minutes. The ladies strolled picturesquely in their long skirts, their tightly laced corsets, their ostrich feathered picture hats, enormous muffs and with their inevitable parasols, whilst the men made a real fetish of their "Sunday best" ; for everyone had clothes which were reserved for the Sabbath. It was the height of the Edwardian era when embroidered fancy waistcoats, bordered by white slips, were in vogue and collars, many of them made of celluloid, were as much as 3 inches high, and it was fashionable to smoke Turkish or Egyptian cigarettes, not Virginian, which sold at 2½d. for 10, and beer was 2d. a pint.

The motor car was in its infancy ; it was equipped with candle lamps, usually of ornamental brass, which in a little while gave way to oil, and then to acetylene. It trundled somewhat unreliably, and very uncomfortably, along the many unmade roads illuminated, or rather locally lighted, by oil or low pressure gas lamps which aggravated rather than improved the safety of night driving, for they cast little pools of light which tended to accentuate the gloom beyond their limited range.

In that year the pioneer of the "people's car" was introduced—the Model "T" Ford, probably the best seller of all cars. The early motorist, wearing a huge fur coat and a deerstalker hat with ear flaps, found it difficult to purchase a gallon of petrol, but could easily have bought kerosene. It was in general use for oil lamps, which in those days were the general form of lighting in the home, although some of the larger houses were lit by gas, and a few by electricity.

At that time Germany pinned her faith on lighter-than-air machines, whilst France, England and America were pioneering heavier-than-air flight ; and how strange the records achieved then seem today. A Frenchman, Louis Paulhan, reached a record height of 977 feet, and his fellow countryman, Delagrange, beat the air speed record at, believe it or not, 53 m.p.h.

Wireless was used for the first time in a major rescue at sea and in that year, after many past attempts, expeditions reached both the North and South Poles. Shackleton discovered the South magnetic pole, whilst Dr. E. A. Cook claimed to have discovered the North Pole, although history awards the palm to Peary, who brought back conclusive evidence of his discovery.

I think I have said enough to justify the claim that the year of the birth of our Society was a vintage year.

Having now dwelt at some length on the past, and having reminded ourselves of the old, I would like to return to the year 1959, and to consider some of the discoveries and developments that have taken place during those intervening years. Research has given us not only new materials without which progress could not have taken place, but also industrial processes with which to use them, and in many cases, with which to make them.

It seemed to me whilst preparing this Address that it should not consist merely of a catalogue in chronological order, of the progress and the discovery of new materials, of their manufacture and of the development of new industrial processes and machines, but rather that it should be told as a story.

Apart, possibly, from guided missiles, modern rockets and space probes, of which I know little, I can think of nothing in this modern age that is more representative or employs more modern

materials and up-to-date knowledge than the aeroplane, and I have always had an amateurish interest in its progress. On the science of aeronautics we will not dwell, but I am going to use the aeroplane as an illustration of some technical advances during the past 50 years. It is, I think, the finest and possibly the only example of a piece of modern machinery which utilises to the full every new invention and discovery and, as such, has proved to be something of a catalyst that has set up a chain of reactions throughout all other industries. Without these advances in materials and their infinite variety of applications, air transport would not have reached its high state of efficiency and safety. In this atomic age the extensive use of isotopes for inspection is of vital importance to this industry. Regardless of the materials, industrial processes such as die casting, forging, injection moulding, vacuum forming, all play their part ; let alone the modern methods of construction of runways, the building of air terminals, conveyor systems, car parks and the complicated organisation of air control by radar and radio, particularly at overworked airports.

Indeed, within the short space of 50 years we have progressed from one of the first controlled powered flights at about 35 m.p.h. to the successful launching of the first crude unmanned space craft with a speed of more than 20,000 m.p.h. With such thoughts in mind, it is not to be wondered that in parallel there have been some profound effects on most other existing technologies and the introduction of new ones, such as electronics.

It is not my purpose here to attempt any historical survey of these developments. Nevertheless, to add perspective to the time scale, it should perhaps be mentioned that it was not until the early 1920's that metal became generally accepted as a material for aircraft structures ; this, indeed, was one of the first radical steps and from it came the development of the extensive range of light alloys that are now in widespread use.

Another such step came during the second World War with the introduction of the jet engine. This, in addition to bringing metallurgical problems of its own, opened up an entirely new set of operating regimes for the aircraft and posed a number of associated structural difficulties.

It is, then, during the past 15-20 years that the specialist demands of the aeronautical engineer have fostered really intensive research on the part of most industries, including our own, and have led to correspondingly far-reaching developments in many branches of mechanical and electrical engineering.

From the materials point of view, the problem has always been one of providing high strength coupled with an acceptable strength/weight ratio. Operating altitudes of 35,000-40,000 feet required for economical fuel consumption for turbine and jet powered aircraft have brought with them the need for a higher degree of pressurisation in the fuselage and as a result this structure has to bear even greater loads from internal pressure than had previously been the case. The new generation of jet airliners, in fact, have a fuselage pressure differential at operating altitudes of as much as 8 p.s.i. Quite apart from having to cope with the steady application of this internal pressure for relatively long periods, the fuselage structure has also to withstand fatigue because of repeated pressure application throughout a long working life—a matter of, perhaps 30,000 applications over 10 years.

Wing structures, too, experience repetitive stresses which similarly are potentially dangerous from fatigue. Some of these applications of load occur at frequent intervals, such as those arising from gusts during flight ; others occur at wider intervals—such as during take-off and landing when the weight of the entire craft is transferred to or from the wing. In consequence, the aeronautical engineer has had to initiate a tremendous amount of research into material fatigue properties.

As a result of all these, the present-day light-alloy airframe of a large civil transport aircraft is a most efficient structure with an acceptably long fatigue life. It has also to be designed to have "fail safe" characteristics so that should any part of the structure fail the whole will not be endangered.

Not only have the higher speeds of manoeuvre and operation made possible by the gas-turbine powerplant added emphasis to the basic strength problem, they have introduced an even more stringent requirement for maintaining the necessary strength in conditions of high temperature. For example, at a speed three times that of sound—already within sight as a normal operating condition—the airframe structure can attain a temperature of the order of 280 deg. C. With some gas-turbine engine components, notably in the region of the turbine wheel and disc, working temperatures of around 800-900 deg. C. are commonplace. Structures that are to withstand the temperature effects for speeds up to about 1,500 m.p.h. aluminium alloys are satisfactory for most purposes. At higher speeds, however, with "soak" temperatures beyond 100 deg. C. a material with better high temperature strength properties is required. For such application there is a trend towards the use of stainless steel ; but

it should perhaps be mentioned that the production of such materials for airframe use is not without its problems.

Recent metallurgical developments include the titanium alloys, which offer excellent strength characteristics at elevated temperatures. Unfortunately, their cost is very high and moreover fabrication of these alloys is most difficult. Nevertheless, they are becoming increasingly used.

The gas-turbine engine with its high-speed rotating assembly of compressor and turbine, and the high temperature of its combustion system, clearly poses a set of problems and requirements peculiar to itself. For this application the high-grade nickel alloys were developed and are outstanding examples.

When it comes to missiles and such devices as satellites, even higher temperatures have to be catered for, and these can, in some cases, be higher than the melting point of the orthodox materials. Research into the use of metals such as molybdenum, beryllium and vanadium and its manipulation for structural application is already being investigated.

In recent years, products from the plastics industry have come to be quite widely adopted and developed for aircraft use. Here, as in the case of metallic materials, the specialists have worked closely with engineers to provide materials suitable for the exacting requirements of aircraft application. There is, however, no real sign of the application of plastic materials to primary airframe structures, but for secondary structures they have proved to be very successful. An indication of the sort of advantages offered by the use of polyester-glass instead of sheet metal is given by the case of a typical wing root fairing for a medium-sized civil aircraft. Although in this case the weights were similar, the plastic unit had two components instead of 25, needed two rivets instead of nearly 600, and for a batch of 25, needed 20 production man-hours instead of 100.

A particularly important application of reinforced plastics to aircraft is in the radomes which have become a feature in all guided missiles, most military aircraft and a good many civil ones. A tremendous amount of work on the development of suitable materials for this task has been done. Not only do they have to provide the radar "transparency" required but they have to withstand some very rough treatment. For instance, at 1,500 m.p.h. a rainstorm would have an effect not unlike that of sandblasting. It is for this reason that more and more attention is being given to the use of sintered metallic oxides in the form of hard ceramics.

For the "domestic" side of aircraft engineering, of course, plastics are invaluable. Furnishings, trims, beading, seats and galley equipment make use of most plastic materials, and acrylic plastic is almost universally used for canopies and cabin windows.

One cannot leave plastics without mention of one particularly vital post-war development in this field. This has been the production of synthetic resins for the metal-to-metal bonding of primary aircraft structures. The advantages of "gluing" metal structural components such as stringers and frames to skin panels instead of using the more orthodox engineering practice of riveting are clearly very great, both in saving weight and production man-hours. Because of the continuous joint so formed, the bonded components have excellent shear strength and compare favourably with riveted joints in this respect. Moreover, when this process is used to attach internal structure to outer skin surfaces there are no excrescences such as those formed by rivet heads or by waves between rivet positions.

Another highly developed process that owes much to aeronautical demands is the electrical spot and seam welding of light alloys. As part of this development there has been considerable progress made in the X-ray inspection equipment of multiple welds of this kind.

Mention has already been made of the growing complexity of modern aircraft and the widening of the conditions in which they operate. Not unnaturally this has been reflected in the development and refinement of their equipment and auxiliary services. Hydraulic systems, for example, used for such duties as flap and undercarriage operation and more recently, too, for flying control systems, have gradually evolved from those using less than 1,000 p.s.i. to the present-day systems employing pressures of up to 4,000 p.s.i. and made up of compact, light and efficient components such as operating jacks, pumps, motors and sundry valves. For all its compactness, the system is none the less extensive and a large aircraft might contain as many as 200 separate hydraulic units and several hundred feet of pipe line. Electric solenoids, switches and circuits are used for sequence switching in these complex systems.

One of the most remarkable of all the more recent developments has been that in the pressurisation and air conditioning systems of modern civil transport aircraft, some having an occupied volume of more than 9,000 cubic feet, and the lessons learned in aircraft application are already being applied in many other fields.

Some idea of the magnitude of the problem can be obtained when it is realised that it must be possible to maintain a rate of change of cabin pressure to the equivalent of an altitude change of 300 ft/min.—which the occupants can accept without discomfort—when the aircraft itself changes altitude at the rate of perhaps 5,000 ft/min.

Temperature control in the cabin is another problem and surprisingly this is more a case of cooling than the reverse. The air delivered by the compressors for pressurising is inevitably at a high temperature and a hundred passengers generate considerable heat; solar radiation adds its share and there may be some kinetic heating of this structure. The system, therefore, must be provided with refrigeration equipment giving a cooling effect of more than 2,000 B.T.U.'s/min. to reduce the temperature of the cabin air to an acceptable level.

Equally rapid strides have been made on aircraft electrical systems needed for instruments, radio and radar equipment, lighting and other services. Again these have grown in a remarkably short time from the simple windmill-driven generator to a complex electric power generation system driven from the main powerplant or even in some cases from a separate auxiliary gas-turbine engine. The present trend is towards the use of constant-frequency 400 cycle 3-phase A.C. power systems with suitable rectification to give secondary D.C. supplies. Generally speaking, the A.C. voltage used in this country is 208 and the D.C. voltages 112 and 28. A typical large installation might have a total electrical power output of some 200 KVA and present forecasts of 600-700 KVA for future aircraft have been made.

The wide temperature and pressure ranges over which this equipment has to operate has given rise to a number of problems and these have led in turn to some important developments. For example, brush failures experienced at high altitudes have led to the development of brushless alternators. In the electronics field, radar techniques and apparatus have received considerable stimulus from the exacting demands of airfield and aircraft requirements for reliable high-performance equipment. Airborne radar in particular has seen considerable refinement during the past few years. Understandably enough, little information is available on radar equipment for service aircraft and missiles, but, here again, developments have been both rapid and far reaching. But an example is the recent introduction of the constant-wave altitude radar system for use with Doppler navigation equipment, bringing useful reduction in weight and size. Another of the latest pieces of radar equipment, a cloud and collision warning radar, weighs a mere 56 lb.; earlier equipment intended for this same task weighed three times this amount.

Whilst I fully realise that what I have said has little direct bearing on our own interests, it may, perhaps, remind us of the fact, however, that not only are we and all others inter-dependent, but our own interests depend very much on the practice and the prosperity of other industries. I am conscious, too, that in this brief survey, I have omitted many startling mechanical advances and that time does not permit me, even in generalities, to cover the subject adequately. I suppose from sonic to supersonic flight and from normal aircraft, the logical step would be for space travel. Whatever those other developments, we must also progress in our own sphere of occupation. We have already progressed from carbon lamps to tungsten lamps, mercury lamps and fluorescent lamps, and now have in view the atomic lamp. I am sure that each in our own way, whether we are concerned with illuminating engineering, research, architecture, consultancy or with manufacture, we are all striving to play our part in this ever changing modern world.

I suggest, too, that our Society is making its full contribution, and that it is even more confident that it can do so in the future than it did when it started fifty years ago.

The Nature of Light

By SIR LAWRENCE BRAGG, F.R.S.

When I was asked eighteen months ago to give this lecture on the occasion of your Golden Jubilee, I appreciated deeply the compliment of being invited to take part in such an important event. I confess, however, that I accepted the invitation rather light-heartedly and as the time drew nearer I regarded my task with some trepidation. When I consulted your Secretary, Mr. Cole, about my talk, he indicated to me that he expected an audience of high academic calibre and that a profound treatment of "wave versus quanta" ideas would be appropriate to the occasion. Such a task is beyond me, and I hope you will not be disappointed with the plan I have chosen. I felt that on this special occasion it might be appropriate to review the history of ideas about the Nature of Light, and to make the talk a figurative pious pilgrimage to the shrines of the great men in the past who have made contributions to these ideas. In doing this I shall only be retelling an often told story, but I do not think this needs an apology. We all, as scientists, are so occupied with the present that we too rarely refresh our memories about the past; in preparing this talk I have personally, at any rate, come to realise how much it has helped me to see past events in perspective and I hope that this review will also be of interest to you.

I propose to outline the beginnings of the rivalry between the corpuscular and wave theories of light, the long dominance of the corpuscular theory, its downfall before the brilliant developments of the classical wave theory of optics, and the emergence of the quantum theory which seemed to bring us back to corpuscles again. Finally I shall attempt to outline the present synthesis of the two apparently irreconcilable views.

I shall begin our review in the year 1600. There were, of course, many speculations about the nature of light in earlier times, one main point of contention being whether the cause of vision proceeded from the object to the eye, or whether the eye sent out rays which, as it were, felt the object. Euclid held the latter view, which we must not regard as altogether absurd. It is on the contrary quite a natural idea, and has been adopted in many of our everyday expressions such as a "piercing eye" or "penetrating insight." It perhaps reaches its highest poetical expression in the words of the novelist who said of the heroine that "she swept the gravel path with her hazel orbs." On the other hand Democritus and Aristotle held that the eye receives something from the object. The Arabs were the great scientists in the dark ages, and Al Hazin in his work on optics written about A.D. 1000 warmly supported this idea.

In the early 1600's Snell discovered experimentally the law of refraction which has since been known by his name. This is a good starting point for our review, because it was the first quantitative expression of a somewhat complex optical law, and it introduces us at once to the controversy between the corpuscular and wave theories. Descartes in his "La Dioptrique" (1637) deduced the law theoretically. He assumed that light corpuscles were attracted by the denser medium, that as they dived into it their velocity was increased to the same extent whatever the angle of incidence, while the velocity parallel to the surface remained constant. This gives Snell's law, but of course both assumptions are untrue. It is a crucial point in Descartes' deduction that light travels faster in the denser medium. Later in the century Huygens in 1678 presented his famous paper to the French Academy of Sciences, the first serious attempt at a wave theory of light though Hooke had speculated on the idea. Huygens supposed that as a wave advances in a medium the particles on the wave front become in turn the centres of spreading wavelets, whose envelope outlines the further form of the wave. He explained Snell's law as due to a slower rate of travel of the waves in the denser medium, as opposed to Descartes' deduction which required a higher velocity. It was nearly two hundred years later that Foucault (1853) proved experimentally that light travels more slowly in the denser medium, and by the time this crucial test was made the corpuscular theory was virtually abandoned.

In addition to explaining reflection and refraction in terms of his wavelets, Huygens gave a construction for the paths of the ordinary and extraordinary rays in crystals of Iceland Spar. (Double refraction had been observed by Bartholinus some ten years earlier.) He assumed the wavelets to be of two types:

A lecture given at the Royal Institution in London on October 15, 1959, being one of a series of four Golden Jubilee lectures. The author is Director of the Davy Faraday Research Laboratory at the Royal Institution.

"Then instead of the hemispherical partial waves which in a body of ordinary refraction would spread from each of these last points, as we above explained in treating of refraction, these must here be hemispheroids."

The first type are spherical and so give rise to an ordinary ray which obeys Snell's law. The second type are spheroids and this explains the remarkable phenomenon that when light falls normally on the face of a calcite rhomb, the extraordinary ray is deflected away from the normal. This construction fills one with admiration for Huygens to whom it is a wonderful tribute when we consider how long ago it was made.

As is well known, Newton lent the weight of his great authority to the corpuscular theory, his main reason for rejecting the wave theory being its apparent inability to explain why light travelled as rays: "To me the fundamental supposition itself seems impossible, namely, that the waves or vibrations of a fluid can, like the rays of light, be propagated in straight lines without a continual and very extravagant spreading and bending every way into the quiescent medium, where they are terminated by it." But it still seems remarkable that Newton did not appreciate the strength of the support for the wave theory. The colours of thin plates were known to him, he had experimented with them. He had deduced the right numerical relationship for "Newton's rings" though it was not he who had discovered them. "Since the vibrations which make blue and violet are supposedly shorter than those which make red and yellow they must be reflected at a less thickness of the plate." In his theory he had to postulate the existence of an ether, a vehicle for the vibrations which governed the fits of easy reflection and easy transmission and so gave rise to interference phenomena. Grimaldi had described the fringes bordering the shadow of a rod and called the effect diffraction, and Newton studied this and other diffraction phenomena. The one missing link was the realisation that the small scale of the waves (which he had correctly deduced) as compared with the size of the aperture restricted the light to a narrow beam. A simple experiment with a wave-trough would have immediately suggested the reason and it seems surprising to us that Newton did not accept this difficulty as a point awaiting explanation in a wave theory for which there was overwhelming evidence, but preferred instead to formulate a complex and almost fantastic corpuscular theory. One has to remember the strange bent of Newton's mind. He was abnormally sensitive to criticism of weak points in a theory, as witnessed by the long delay in publishing his theory of gravitation. Further, the greatest of scientists thought little of the importance of science. In a letter to Hooke in 1679 he wrote ". . . I had for some years last been endeavouring to bend my self from Philosophy to other studies in so much that I have long grutched the time spent in the study unless it be at idle hours for a diversion." He only tentatively adopted the corpuscular theory as the occupation of "an idle hour" and can hardly have foreseen the effect on succeeding generations to whom his slightest word was law. It is perhaps not so strange that one apparently irreconcilable fact caused him to abandon further speculation.

Newton started his first investigations into the components of white light in 1666, and described them to the Royal Society in 1672. Science moved at a leisurely pace in those days. His first reflections on the origin of the colours is fascinating.

"Then I began to suspect, whether the rays, after their trajection through the prism, did not move in curve lines and according to their more or less curvity tend to divers parts of the wall. And it increased my suspicion, when I remembered that I had often seen a tennis ball struck with an oblique racket, describe such a curve line. For, a circular as well as a progressive motion being communicated to it by that stroke, its parts on that side, where the motions conspire, must press and beat the contiguous air more violently than on the other, and there excite a reluctancy and reaction of the air proportionably greater. And for the same reason, if the rays of light should possibly be globular bodies, and by their oblique passage out of one medium into another, acquire a circulating motion, they ought to feel the greater resistance from the ambient aether, on that side, where the motions conspire, and thence be continually bowed to the other. But notwithstanding this plausible ground of suspicion, when I came to examine it, I could observe no such curvity in them."

The well-known "experimentum crucis" of passing samples of the spectrum produced by one prism through a second prism led him to the right answer.

In 1676 Römer presented his paper to the French Academy of Sciences on the observed irregularities of the eclipses of a satellite of Jupiter. When the earth is nearest to the planet the eclipses are seen earlier than would be expected from the average period of the satellite ; when the earth is at the other extreme of its orbit furthest from Jupiter they are later. Römer explained

this by assigning a finite velocity to light. He calculated that light took 22 minutes to cross the earth's orbit (the actual value is 16 minutes 32 seconds). His thesis was not at first universally accepted, but in the next century it was verified by James Bradley's observations of the aberrations of the fixed stars. I quote the well-known story as related in the article on Bradley in the Dictionary of National Biography :

> "Accompanying a pleasure party in a sail on the Thames one day about September, 1728, he noticed that the wind seemed to shift each time that the boat put about, and a question put to the boatman brought the (to him) significant reply that the changes in direction of the vane at the top of the mast were merely due to changes in the boat's course, the wind remaining steady throughout. This was the clue he needed. He divined at once that the progressive transmission of light, combined with the advance of the earth in its orbit, must cause an annual shifting of the direction in which the heavenly bodies are seen by an amount depending upon the ratio of the two velocities."

To sum up, in the years 1600-1700 reflection and refraction, double refraction, polarisation, dispersion of colours, interference, diffraction, and the finite velocity of light had all been discovered and subjected to an advanced degree of quantitative examination. Most of the fundamental optical phenomena were in fact known.

In contrast to the preceeding century, the years 1700-1800 present an almost complete blank as regards optical discoveries. The only achievement of note was the realisation by Dollond that refraction and dispersion are not proportional as Newton had believed, and so that it was possible to construct achromatic lenses. His discovery, though only a minor event in our survey, had a great importance in effecting improvements in optical instruments. The blight cast over this century is generally ascribed to the shadow of the great Newton. But it is perhaps not a coincidence that the century of pure reason, while producing a series of brilliant mathematicians, was so arid as regards science, which flourishes best in a rich compost of imagination and apparently often illogical intuition.

And then, as if the beginning of the new century marked an actual turning point, a brilliant series of advances appear from 1800 onwards. The century starts with Thomas Young, who first formulated the principle of interference in a paper read to the Royal Society in 1801. Young was at that time Professor of Natural Philosophy in the Royal Institution, and we possess the original wave-trough with which he tested his ideas. To quote from his paper : "When two undulations, from different origins, coincide either perfectly or very nearly in direction, their joint effect is a combination of the motions belonging to each." His most famous experiment is of course that in which he passed sunlight through a pinhole (so achieving what we would now call the necessary "coherent source") and used it to illuminate two pinholes in a further screen. Where the patches of light overlapped, he observed the interference fringes. He explained the colours of thin plates by the same principle, and also the colours produced by scratched surfaces, in effect diffraction gratings. Young's great contribution was thus the idea that beams from two sources could annul each other in certain directions while reinforcing in others, a vital blow to the corpuscular theory. But his contemporaries did not see it in that way. To quote from Cajori's "History of Physics" :

> "Young's articles were declared to contain 'nothing which deserves the name either of experiment or discovery,' to be 'destitute of every species of merit.' 'We wish to raise our feeble voice,' says Brougham, 'against the innovations that can have no other effect than to check the progress of science.' After exposing the law of interference as 'absurd' and 'illogical,' the reviewer says 'We now dismiss, for the present, the feeble lucubrations of this author, in which we have searched without success for some traces of learning, acuteness, and ingenuity, that might compensate his evident deficiency in the powers of solid thinking, calm and patient investigation, and successful development of the laws of nature, by steady and modest observation of her operations.' "

Young remained puzzled by rectilinear propagation. He wrote in a private letter : "If a ray of light has constantly such a tendency to diverge into the path of neighbouring rays as Huygens assumes, then I don't see how, even in the most transparent medium, it can travel a way, however short, without being completely extinguished."

Fresnel did not know of Young's work when he started his researches into optics, to which he devoted his spare time as a recreation while employed by the government on building state roads. When Napoleon returned from Elba, Fresnel, who had joined the army which opposed him, was suspended from his duties and the leisure he thus enjoyed gave him an opportunity to concentrate on optical phenomena. He rediscovered interference and embodied his results in two papers presented to the French Academy

of Sciences. He worked with crude and improvised apparatus. It is recorded that his slit system was made by the village blacksmith, and that when he wanted an approximately monochromatic point source he drilled a hole in an iron plate and filled it with a drop of honey which acted as a yellow lens. His papers had a poor reception, though the young man found a warm friend in the kindly Arago. Laplace and Biot were violently opposed to his ideas. Then came the great occasion when Arago and Ampere persuaded Fresnel to enter for a prize offered by the Academy, the subject being 'A Theoretical and Experimental Investigation of the Phenomena of Diffraction and Interference." The result was Fresnel's brilliant treatment of the diffraction of light. One cannot but be overcome with admiration for the originality and elegance of Fresnel's work. Let us remind ourselves what a formidable problem he tackled. He set himself to analyse what no one had previously attempted, the form of the light waves after they had passed an obstacle or been limited by an aperture. A rigorous solution demands a mathematical treatment of precisely how the waves interact with the material of the boundary. Fresnel bypassed the difficulty by using Huygen's concept of secondary wavelets and summing up their effects. He showed that a point in a wave front only receives its effects from a small zone of the preceding wave, in a line with it and the source. The wavelets from the rest of the sphere cancel out, and hence he explained rectilinear propagation, and removed the apparent contradiction in Huygens' principle. In spite of the great prejudice against his views, he was awarded the prize by the judges.

Fresnel's other great contribution was his treatment of double refraction in terms of transverse vibrations. Here he was indebted to Thomas Young who in **1817** wrote to Arago on the possibilities of a new hypothesis "a transverse vibration, propagated also in the direction of the radius, and with equal velocity—and this is polarization," and later compared the polarized waves to the undulations in one direction or another of a stretched cord (an analogy we still use in classes). Arago showed Young's letter to Fresnel who at once saw that the idea explained the non-interference of beams polarized in perpendicular planes, and went on to develop his theory of double refraction.

A charming episode of the time was Fresnel's warm tribute to Young when he learnt that the latter had a prior claim to the discovery of interference, and Young's reply expressing the warmth of his admiration for Fresnel's ideas.

I can only refer briefly to other achievements in the 1800's. In **1814** Fraunhofer made diffraction gratings and measured wavelengths. In **1849** and **1850** Fizeau and Foucault measured the velocity of light over terrestrial distances, and in **1853** Foucault showed that light travelled more slowly in water than in air. In **1858** Kirchhoff and Bunsen founded spectrum analysis by showing that each element emits and absorbs characteristic wave lengths.

This brings us to the crowning achievement of the century, Maxwell's Electromagnetic Theory of Light. The crucial conception is the existence of "Displacement currents" ; just as Faraday had shown that a change in magnetic induction gives rise to an electro-motive force, so Maxwell had the inspiration to see that a change in electrical induction should give rise to a magnetomotive force. He arrived at this idea by a most complex mechanical model of the ether with rotating tubes of force interlinked by idle wheels. I confess I have never had the courage to follow his reasoning, and am only comforted by the knowledge that others have felt the same. Hertz wrote :

> "Many a man has thrown himself with zeal into the study of Maxwell's work, and, even when he has not stumbled upon unwonted mathematical difficulties, has nevertheless been compelled to abandon the hope of forming for himself an altogether consistent conception of Maxwell's ideas. I have fared no better myself."

This mechanical model is thrown away, however, when the elegantly symmetrical final equations are deduced. It is like the untidy scaffolding erected in building a bridge, which is removed when it has served its purpose, leaving a simple shapely arch spanning the gulf.

In **1888** Hertz crowned Maxwell's achievement by showing that it was possible to detect the electromagnetic waves from an oscillatory source and that they could be reflected, refracted, and polarized like light waves.

The end of the nineteenth century marks the completion of the fair edifice of classical optics. The main phenomena were discovered in the seventeenth century, the eighteenth was a time of no progress, the wave-theory of light assumed its final form in the nineteenth.

Again at the turn of the century a new realm was opened up by Planck's enunciation of the quantum theory. Planck was led to the conception in seeking for an explanation of the spectral distribution of energy in black-body radiation. He found it necessary to assume that radiant energy could only be emitted in quanta of $h\nu$, and that thermal energy had to be accumulated until a sufficient instalment was available for a quantum.

Five years later Einstein made the further step of assuming that all radiant energy exists in energy quanta $h\nu$, where h is Planck's constant and ν its frequency. The interchange in energy between radiation and matter takes place in bundles of amount $h\nu$.

This is the kind of effect one would expect from light corpuscles, and the wheel appears to have turned a full cycle. First came the corpuscular theory upheld by Newton, then the brilliant work which appeared to establish the wave theory on so firm a basis, then the proof that the effects of light, when observed, appear at localised points as if light bullets were spraying upon the recording medium. One grain here or there in a photographic plate exposed to light receives a full quantum and suffers a damage which enables the developer to reduce its silver. One electron here and there in a cloud chamber traversed by X-rays gets a direct hit and becomes visible as a track on expansion. To round off the story, it is discovered that matter has this same dual character of wave and particle. Neutrons and electrons behave as waves, and can be diffracted by crystals.

Are we to believe in waves or in particles? It was a favourite saying of my father's that we must consider light as being waves on Mondays, Wednesdays, and Fridays, and as particles on Tuesdays, Thursdays, and Saturdays. Perhaps we may state this duality in a somewhat more general form. What we actually observe as the result of an experiment is particulate. A light quantum delivers over its whole energy at a point, an electron is recorded as the track of a particle in an expansion chamber. On the other hand when we seek to predict the result of a particular experiment, we must cast our analysis in the form of waves. In our experiment, light falls on a grating or is diffracted by an aperture. We assign a wave-length to the light, and calculate the distribution of energy due to interference. Electrons fall on a crystal; we assign a wave-length to them and calculate the resulting interference pattern. In each case the relation between energy and wave-length is given by Planck's equation $E=h\nu$. The intensity we calculate for our waves gives correctly the *chance* of finding a quantum or electron at a given point, or their statistical distribution.

Whether they are waves or particles is a matter of tense. Before they are observed they must be treated as waves; when they have been observed they are recorded as particles. Our prediction of the future must be expressed as waves filling all space, our history of the past as a series of particles at definite points. It is as if the moment "now" were a kind of coagulating filter, with a wave-picture of the universe in front of it, and as it ever sweeps forward in time it strains the waves through its meshes and leaves behind a history of particles both of radiation and matter. In some such way there must be a synthesis of the old particle and wave controversy as to the true Nature of Light.

The lecture was illustrated by demonstrations of refraction, double refraction, Newton's rings, a repetition of Newton's classical experiments with a prism, Young's principle of interference using his original wave trough, Fresnel's principles of diffraction repeated with centimeter waves, and the photo-electric effect.

The Generation of Light

By L. J. DAVIES, C.B.E., M.A., B.Sc., M.I.E.E.

To generate light, in a way that provides the most efficient, reliable and acceptable form of light source, is the task of the lamp engineer. He will select one of the forms of energy such as thermal, electrical or chemical, choose one of the light producing processes—incandescence, luminescence from gases or from solids—and design a system, called a lamp, in which the conversion is caused to occur. Then, and to the engineer this is still an essential part of the overall job of generating light, he designs the equipment that will enable the lamps to be made in the quantities required. These are considerable. An estimate suggests that 5,000 million lamps are currently being made annually. In virtually all of them conversion is from electrical energy and all of them use basic light producing processes that have been known to man for centuries and to science as it has unfolded. The work that has brought light generation to its present stage has been that of the technologists. In some cases lamps have been under steady development for so long that it would be expected that little more could change, nevertheless development with very interesting possibilities is active in all directions. A main reason for this is that technology nurtures itself and the more developments there are in one the more all the others are helped. When a number come together at the right time, and especially if this coincides with demands for new lighting levels, created by advancing standards of living, there will be an upsurge of progress. In this lecture a "curve of progress" will be shown for each basic light producing process, in order to provide perspective for the present position on development.

There are these different processes because a light source, which is essentially a piece of matter containing energy which it is spontaneously losing by the radiation of electromagnetic waves, can do this by different mechanisms. It can contain kinetic or vibrational energy and it is then hot matter. If hot enough, part of the energy it loses can be seen and the process is called incandescence.

Or it can contain energy not connected with heat or motion, but with the arrangement of the internal parts of the atoms, the nuclei and electrons. These can exist in a number of different ways or "states" each containing different amounts of potential energy. The states of higher energies can change spontaneously to states which contain less, simultaneously radiating the energy difference as electromagnetic waves. Such processes may be called luminescence. Although basically the same, some of the features of luminescence from free or gaseous atoms are so different from luminescence from solid bodies that it is convenient to treat them separately. We will, therefore, for the purposes of this lecture, classify the basic processes as incandescence, gaseous luminescence and solid luminescence.

A lecture given in London on October 19, 1959, being one of a series of four Golden Jubilee lectures. The author is Director of Research and Education, Associated Electrical Industries (Rugby) Ltd. and a Director of A.E.I. Lamp & Lighting Co. Ltd.

Incandescence

Let us start with an elementary representation of the incandescent process, portraying a solid as consisting of atoms arranged in a regular lattice held together by forces which are represented by elastic strings. The process of heating the body is that of introducing energy which causes the atoms to vibrate. When this happens electromagnetic waves are radiated. As the input of energy increases the intensity of vibration and the proportion of shorter waves increase, and the colour of the light becomes whiter. It has a continuous spectrum.

The curve of progress of incandescence (Fig.1) shows the main steps that have led to a world production of nearly 5,000 million lamps per year. First carbon as a filament, then various metals, then drawn tungsten straight, and then coiled, and later coiled coil. The technological steps are well known and in retrospect each looks easy. But to see how full of detailed study each one has had to be, let us take one example, the apparently unexciting one of providing the bulb. When this Society first started bulbs were blown by hand. Now they are made by machine at the rate of about 1,000 per minute. But at such a rate much can go wrong and advances in many other technologies, metallurgy, electronics, photography and illumination, etc., are necessary before such production can be established. For example, a rotary arm transfers bulbs from the machine to the annealing belt. How do the bulbs get safely from the moving moulds to the rotary arm? To study the behaviour of a mechanism of this sort one requires the development of the high speed

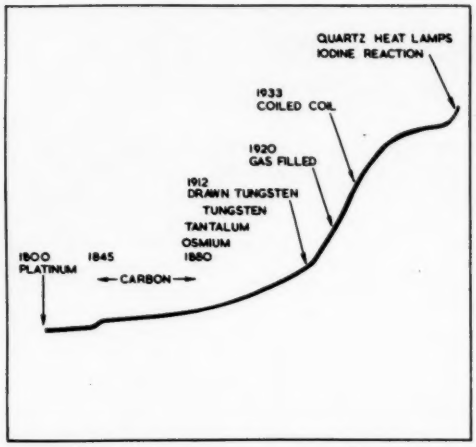


Fig.1. Progress curve, incandescence.

film technique, which in turn, operating at say 900 frames per second, requires a lamp such as the xenon compact arc 2 kilowatt.

The outstanding claim of the incandescent lamp cannot rest on one of efficiency of energy conversion. The major virtues of the lamp are its basic simplicity, great reliability of behaviour and fitness of purpose. This has required a great range of development carried on continuously. An example of this is some work done in connection with filaments to withstand vibration. Take the case of the development of lamps for automobile lighting. Severe and complex vibrations are possible and it is first of all necessary to know what these are. One method is to take a tape recording of the vibrations experienced in a car in operation. This is brought back to the laboratory and ideally the tape would then be caused to play back the vibrations on to the lamp. So far a suitable "play back" device has not been developed. Therefore, an analysis of the main frequencies is made and each in turn applied to the lamp by means of a variable frequency generator.

The ordinary general purpose lamp is so fully developed that it may easily be imagined that it has reached stability of design. However, there seems to be no end to the requirements for special applications and each one of these may be responsible directly or indirectly for bringing about a new upward trend in the progress curve. There is, for example, the sealed beam automobile lamp with its requirement of a narrow angle precisely controlled beam. With its conception of internal reflector and precision of setting, this lamp seems extremely important for it introduces the thought that when the life of a lamp is very long, as an automobile head lamp bulb is compared with the night life of a car, the lamp can be elaborated to function in the best possible manner.

The silica lamp

A special development that may stimulate other interest is the silica infra-red lamp. Developed for kinetic heating simulation tests on aircraft structures it can, when suitably arranged in massed banks, raise the surface temperature of structures by as much as 2,400°C. in less than half a second (Fig.2). Such massed banks can take power of the order of megawatts. Almost before the development of this lamp for a special application a further development is being tried

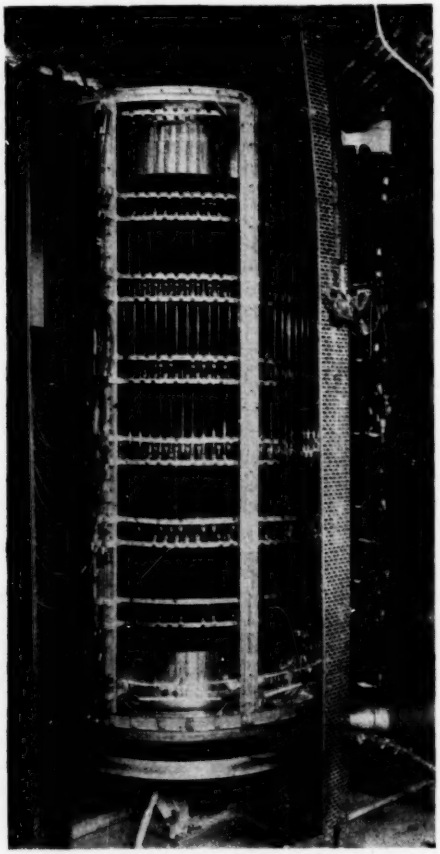
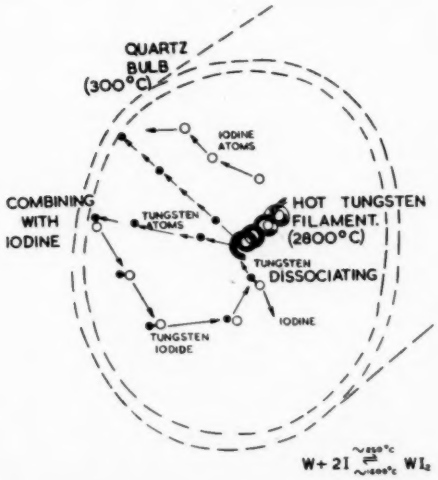


Fig.2. A bank of silica infra-red lamps (with acknowledgements to the Director, R. A. E. Farnborough).

that may make it useful for the specialised lighting field and possibly even, in time, the general purpose field. One strives to increase the efficiency of the incandescent lamp without decreasing the life. One way to do this is to increase the temperature of the filament without an increase in the rate of evaporation. This has been done by physical methods such as coiling and gas filling and now a chemical method shows promise. If we could return some of the tungsten to the filament as fast as it is evaporated, this would be equivalent, of course, to slowing down the rate of evaporation. One way to do this is to use a chemical compound of tungsten which will form at the temperature of the bulb and decompose at the temperature of the filament, depositing tungsten on the filament and releasing the chemical to carry on the cycle.



Tungstic iodine is a suitable chemical. It is necessary to have a bulb temperature not too low or otherwise brown tungsten iodide would deposit, nor too high or otherwise tungsten iodide would not form. In the diagram (Fig.3) of the process the wall temperature is shown as 300°C. This is a minimum temperature. Experimental results on iodine lamps indicate that exceptionally good lumen maintenance results may be obtained so that one now has the possibility of a small, very efficient, high wattage tungsten lamp with no deterioration of light output. The photograph (Fig.4) shows an experimental lamp that has first been run without iodine and then cleared by being run with iodine.

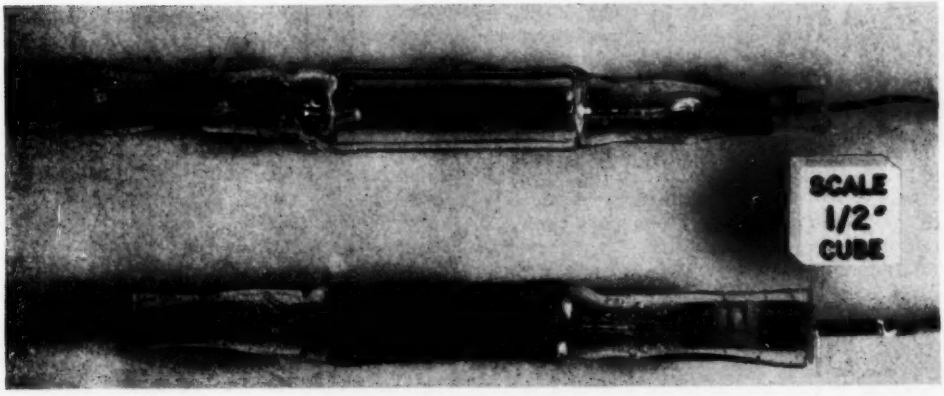
So far, no experience yet exists to say just in what ways a lamp of this type will be most valuable. But I would like to quote from a recently published American paper which suggests a use in a space ship :

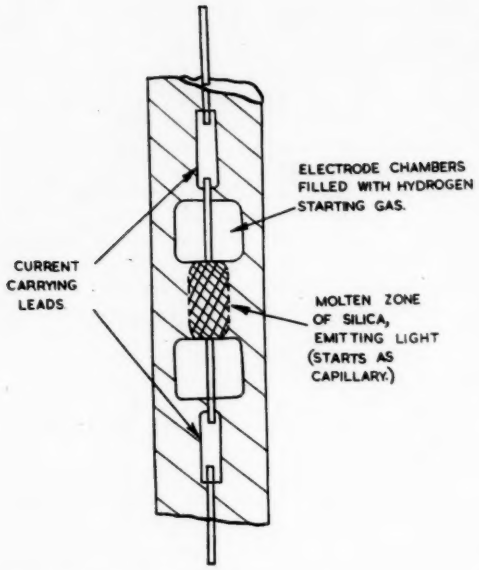
"One method being investigated is to actually carry in each space ship a small portion of Mother Nature's life sustaining phenomena, that of photosynthesis. . . . With a quartz filament lamp as a sun and a newly developed high reproductive strain of algae . . . has reduced the volume of algae required to sustain man to one twentieth of that considered necessary. Thus this new lamp, in combination with oxygen regenerative equipment, may enable man to travel in outer space or beneath the sea for indefinite periods of time."

This seems an appalling prospect and may be

Fig.3 (left). The iodine cycle in a tungsten filament lamp.

Fig.4 (below). Comparison of blackened and clear quartz tungsten lamps.




ELECTRODE CHAMBERS FILLED WITH HYDROGEN STARTING GAS.
CURRENT CARRYING LEADS
MOLTEN ZONE OF SILICA, EMITTING LIGHT (STARTS AS CAPILLARY)

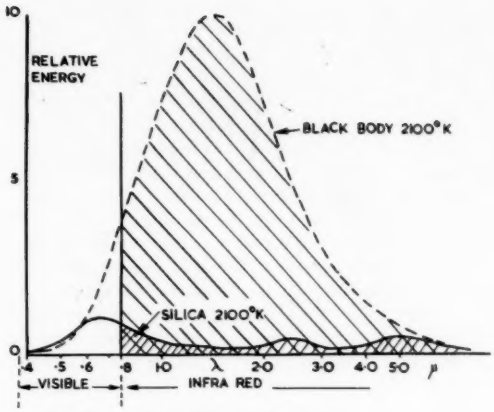


Fig.5 (left). Fused silica lamp.

Fig.6 (above). Spectral energy distribution of fused silica.

the only black mark to be recorded against lamp development !

The selective radiation lamp

Another way in which the efficiency of the filament can be increased is to cause it to require less energy to maintain it at a given temperature. This is possible if the filament radiates selectively emitting the same quantity of luminous radiation but less infra red.

A number of selective radiators has existed but none has survived. The Welsbach mantle, the Nernst filament and the lime light are examples. How useful and important it would be if a selective incandescent tungsten filament lamp could be made. So far there is nothing significant to report on this subject. However, to illustrate the effect, Fig.5 shows a "lamp" in which the radiation comes from quartz. This, as can be seen from Fig.6, has quite a different radiation from that of a black body to which normal filaments approximate. These curves have been drawn so that the amount of visible energy radiated is equal in each case. The great difference in the amount of non-visible energy radiated can be gained by estimating the respective areas of waste energy. The light is blue compared with a tungsten filament operating at the same temperature. Current is conducted along the molten centre of a rod of vitreous silica and the molten silica is held in position by the "frozen" outside walls and the lamp itself has no filament, gas, or vacuum in the ordinary sense. The lamp has no future either in the ordinary sense for, as at present designed, it can only light once !

These examples indicate that, under the pressure of modern technological developments, even the ordinary incandescent filament lamp, long thought to have reached its zenith of development, could well make an upward swing of progress.

This could be expected to be the case to a greater degree with the basic processes of gaseous and solid luminescence. Let us see.

Gaseous Luminescence

Consider a model representing a single free atom and including three tracks to represent electron orbits.

According to modern quantum theory such a representation cannot be correct. The electron is described as not actually moving in orbits but as having a probability of being in a certain region of space at a given time. The supposed changes in orbit correspond to changes in the distribution of the probability in the space surrounding the nucleus. However, this representation is simple and well known. The inner or potential energy of such an atom is associated with the orbits of the elctrons. If an electron is caused to be in one of the outer orbits by the absorption of energy, it may jump spontaneously to an inner orbit and when it does the energy released is radiated as electromagnetic waves. The more different the orbits the greater the

energy difference and the shorter the wavelength. We may thus get red light from a jump between two close orbits and blue light from a jump between two distant orbits.

Only a discrete number of orbits is possible in a single atom; thus only a discrete number of specific wavelengths of light are produced by this process, and we have the characteristic line spectrum.

This is the basic process of light production known as gaseous luminescence. It requires almost exclusively electrical energy as the primary source, and as soon as this became available in sensible quantities, from either rotating frictional machines or electrochemical cells, man-made luminescence in discharge tubes became possible as a fascinating and happy field of experimentation. The effects are, indeed, attractive although they require considerable care to demonstrate. If a potential is applied across a gas at atmospheric pressure nothing visible happens. However, if the pressure is gradually reduced a state is reached when current can be passed and the gas filling becomes luminous. It then goes through various changes showing ripples of light, discs and other well known patterns.

It is work such as this which started off the curve of progress for the gaseous luminescent process (Fig.7). No real thrust occurred for some decades but a definite point of interest happened when Cooper Hewitt and Moore introduced tubes of value for advertising and blueprinting. But the significant happening was when in the early thirties there emerged for street lighting two quite dissimilar discharge lamps, mercury and sodium vapour respectively. Both, making considerable calls on other technologies for special glasses, seals and electron emitting cathodes, have initiated noteworthy developments, and progress still continues. The mercury vapour lamp has provided many groups, medium pressure, high pressure, glass envelope and silica envelope, and rare gas, instead of mercury as filling. The sodium lamp has remained as it started, plain sodium, but with a steady increase in reliability and efficiency and a recent spectacular leap—it becomes almost the lamp of the year with its jump to 100 lumens per watt.

The 100 lm/w sodium lamp

Figure 8 indicates the advance that has been made recently in sodium lamp efficiency, while at the same time the wattage input has been increased from the previous maximum of 140 to 200 watts.

This is a noteworthy increase and it is not unlikely that further increases may be made. It has been achieved by bringing together a number of factors that theoretical considerations indicate are beneficial to design. Apparently simple, the light producing discharge in sodium vapour and neon is quite complex. Here are some of the factors :—

Sodium vapour containing excited sodium atoms can be opaque to sodium light. This can be demonstrated, simply, by viewing a sodium source through a sodium flame. The flame will appear black because of the absorption of light by the excited sodium atoms in the flame.

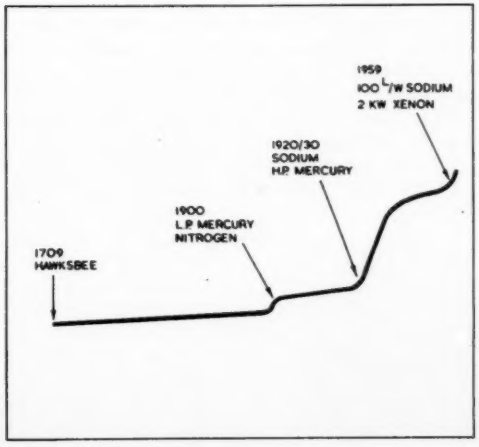
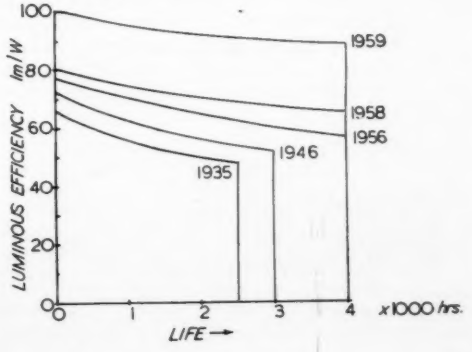


Fig.7 (left). Progress curve, luminescence from gases.

Fig.8 (below). Performance improvement in sodium lamps. (Based on 140-watt lamp 1935-58, and 200-watt lamp 1959.)



Next and obviously, there must be sodium vapour present in the required amount; the forces that can remove it are thermal gradients, as can be shown by cooling a lamp, and electrical fields through which charged ions will move. If a part of the lamp is cooled, the vapour will condense there into liquid sodium. If a lamp has been operated on D.C. for some hours all the sodium will have been carried to the cathode. If the current is reversed, the sodium will migrate to the other end. One should therefore avoid thermal gradients, which the vacuum jacket does, and electrophoresis; one runs the lamp on A.C. of course, but even so it will not be possible to avoid some movement of sodium from these causes. A reservoir of sodium is therefore necessary. Another factor is the slow rate of diffusion of sodium, and a number of reservoirs are advisable so that the sodium does not have far to diffuse to make good any shortages. It is thought that there can be a continuous removal by a pumping action within the arc. If a projection of a tube is examined it is observed that light is coming mainly from the surfaces; this is more marked as the current density increases as can be seen from a stroboscopic projection. It is suggested that sodium vapour is carried to the walls under the field caused by charged walls and may create a starvation effect in the tube unless there are well distributed reservoirs that will bring about replenishment. But at the temperature of operation sodium is liquid and the reservoirs should be firmly anchored pockets offering minimum obscuration.

Next, consider the discharge conditions that are required for maximum sodium excitation. These are as high an electron temperature as possible for the current through the lamp, and this condition is secured by a high surface to volume ratio and a low pressure of sodium vapour. The problem is therefore to design a tubular lamp of flat rectangular cross section with a continuous line of sodium reservoirs. The tube must be very well thermally insulated and made from a glass that absorbs the minimum neon and sodium. The flat rectangular cross section is not easily made and is mechanically weak and easily implodes under a vacuum. However, a simple piece of design work provides a form of lamp that provides a solution to most of the problems (Fig.9).

Elongated dimples are pressed in the lamp and give it at the place of the dimple a flat rectangular cross section bent into the form of a letter "C." Its neighbours ahead and astern are dimpled into the tube on the reverse side, and so on for the length of the tube, forming connecting pieces between the dimples that are also of thin rectangular cross section. The combination is strong enough to resist atmospheric pressure and provides a place for sodium reservoirs at the extremities of the "C."

It is possible in the laboratory to get from the arc itself at low current densities efficiencies as great as 400 lm/w. Although nothing like this is practicable the work being done at many centres is likely to lead to lamps of efficiencies greater than 100 lm/w.

The xenon high pressure lamp

As an example of a noteworthy development in the "mercury vapour" lamp, we will take the xenon high pressure lamp since this, to a very large extent, can trace its ancestry in a direct line back to the high pressure mercury vapour lamp of the early thirties. After the introduction of the 400-watt mercury vapour lamp for street lighting, it was not long before the length of the lamp for the same or higher wattage was contracted, and a very bright and compact lamp resulted. This compact light source suffered from some disadvantages that prevented it from having serious application in those very jobs for which it seemed almost ideally fitted, viz. for searchlights and cine projection. Because one had to have a thermal build-up of pressure before the lamp became bright, it had a "run up" or warming up time of five minutes or so. If it was switched off hot one had to have a "cool down for a re-start" period before one had the warming up time, a total delay of some ten minutes or so. Finally, the radiation was of practically no value for coloured films.

Since xenon is a permanent gas one can fill the

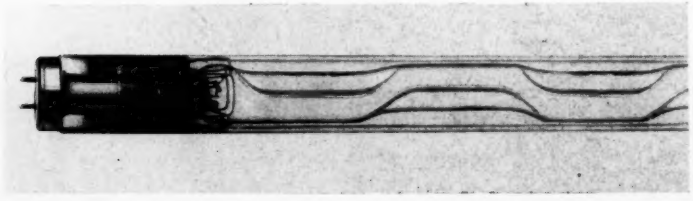
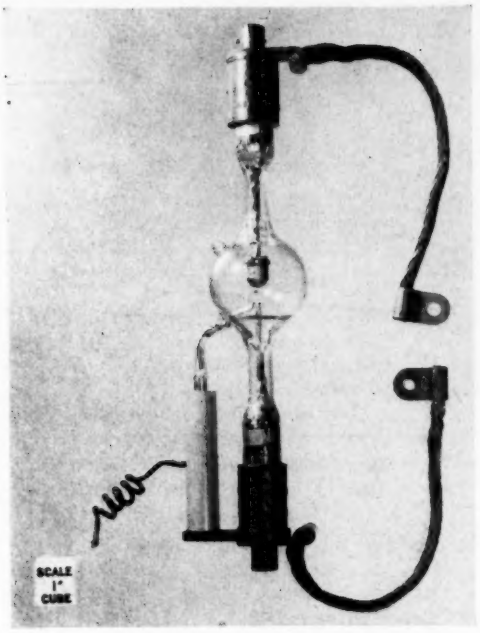


Fig.9. Close-up of 200-watt sodium linear lamp.



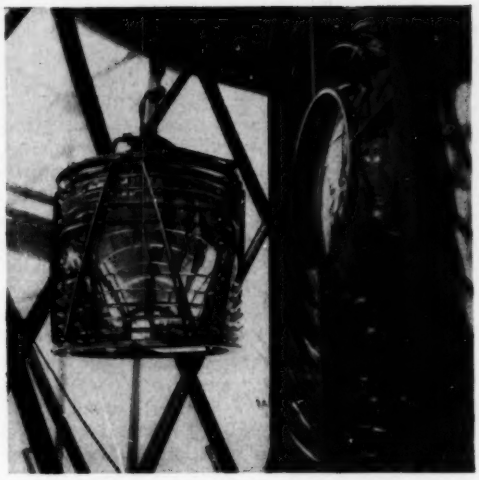


Fig.10 (left). A typical xenon lamp.

Fig.11 (above). Size comparison between a xenon lamp unit and a conventional lighthouse optic.

lamp to any desired pressure : the arc when struck is compact immediately : there is no warming up period. The filling pressure is four atmospheres and therefore just in case it should explode it is always operated in an enclosure, and in transit should always be protected by a cover. A typical lamp is shown in Fig.10.

Since the pressure on starting is high, a third electrode is fitted and is connected to a circuit arranged to give a high voltage pulse. This means that the lamp can be started and restarted almost as quickly as a tungsten lamp. On starting the main current of 80 amperes is not switched since no current flows until the starting current causes the initiation of the arc. The arc current can be extinguished without main switching, since it can be "blown out" by means of a magnetic coil. These features, coupled with the absence of fumes and the ability to arrange for prefocusing make it of interest to those responsible for the modern development of automatic lighthouses. The research staff of Trinity House are obtaining results which they consider very encouraging, and are attaining beam intensities up to 1 million candle power using a small fixed drum lens of some 2 or 3 ft. in diameter with the lamp flashed electrically. It is to be hoped that this lamp will assist Trinity House in its search for more compact lighthouse plant capable of unattended automatic operation. Fig.11 shows a striking size comparison between an experimental unit with a xenon lamp and part of a conventional lighthouse optic.

Similar considerations make this lamp of interest for the cinema—the desire for automation in the operating box : also the lamp has to provide a suitable rendering for coloured films. The nature of the spectrum of xenon is such that, although it is a line spectrum, the larger number of lines and their broadening under the high pressure of operation make it an extremely good colour rendering source, which gives excellent reproduction of colour film.

Already several hundred cinemas in this country are using this lamp which, as it is further developed (and this is likely to go both in the direction of higher pressures and higher currents), may well have a number of important beam-producing uses capable of remote and/or automatic control.

The envelope of the xenon lamp is of fused silica as is, of course, that of the latest achievement in the incandescent lamp. When the I.E.S. first started, the mechanisation of metal/glass seals for the incandescent lamp was something just beginning to emerge. Much work was done by hand by glassblowers who were endowed, so far

as ordinary mortals are concerned, with special skill. If, instead of glass, one had to work fused silica and make seals through it, one had to belong to an esoteric few. Within the last few years machines have been developed that will make molybdenum foil seals through silica. It is possible that new glasses will be developed having even better temperature resisting characteristics than silica, and that will work as easily or more easily. The possibility is, therefore, that machine production of lamps like the xenon or the iodine lamp may enable new lamp types to be developed for general use in certain directions ; if this proves to be so, both the curves of progress of incandescence and gaseous luminescence will take a powerful upward thrust some time in the next decade.

Solid Luminescence

The light producing process involved in luminescence of a solid is essentially the same as in the case of a free atom. There are, however, many more possible energy states which the electron can occupy. Also, although when those states of lower energy are involved, behaviour may be very similar to that in a free atom, when an electron possesses a large amount of potential energy it may not move in a closed orbit at all. It may escape altogether from the influence of its original atom and wander through the lattice. Before it can be accommodated in an orbit of an atom, it must find one which is not already occupied. Often such a place is found most easily near to an impurity atom or defect in the lattice—then in it jumps and emits radiation. During this process some of the potential energy may be transferred into kinetic energy of vibration of the atoms nearby, and thus less may be available for radiation and the wavelength of the radiation is consequently longer. Because of the great number of possible energy states, and because energy can be lost to the lattice in this way, the spectral lines associated with single atoms are broadened out into broad peaks which may merge together. Thus solid (or liquid) luminescence has a spectrum which is more or less continuous over a certain range.

The curve of progress of solid luminescence (Fig.12) starts much as does that for gaseous, at the turn of the sixteenth century. Names such as the Bologna stone, Balmain's phosphorus, and brews of oyster shells and sulphur take us along but not upward. The upsurge of progress started in the late thirties and is still going on, due to two specially important applications—the tubular fluorescent lamp and to television.

But before dealing with these latest developments, in order to note the way in which solid luminescence can be brought about by various kinds of activation, consider the firefly. Here is a case of bio-chemical energy being used to produce luminescence from a solid, and so far as the light production process is concerned, it is the same as that in a television tube or a fluorescent lamp. I thought probably we could not show actual bio-chemical luminescence but, through the good offices of a friend, I found a supply house in New York which said they were sorry they could not supply Luciferin or Luciferase but that they could supply dehydrated firefly tails packaged in 5-gram lots. My friend has extracted the active component from these tails so that by mixing two liquids a light is produced from very much the same materials as would be used by the original insects.

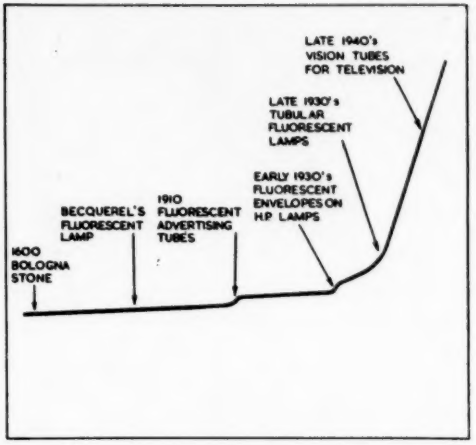


Fig.12. Progress curve, luminescence from solids.

An extremely interesting way of absorbing energy into a solid is by causing the electric fields produced by a displacement current when the solid is part of the dielectric of a condenser to cause electrons to be freed into the lattice space. This provides a lamp that does not require a vacuum or a gas or a cathode and is known as the electroluminescent lamp (Fig.13). It occupies very little volume and is very attractive for certain specialised applications such as indicating lamps, for it consumes very little current, has no filament to fail or vacuum to leak, and is robust in construction. Its use for general lighting, however, is restricted at the moment by its low efficiency—which cannot be made much more than 10 lm/w—and the very low loading to which, at present,

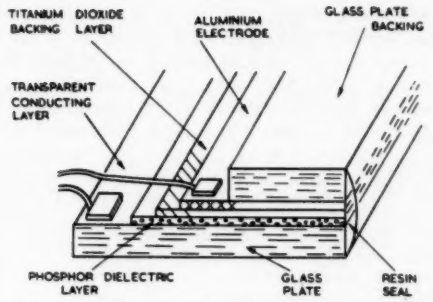


Fig.13. Construction of an electroluminescent panel.

lamps have to be restricted. The attraction of the lamp lies in its future possibilities and for certain specialised applications such as its use with a high speed counter. Owing to the absence of any thermal lag there is immediate response and a powder can be chosen having no phosphorescence. At any instant the counting stops the count can be read and, if necessary, from a considerable distance. It is not easy to think of any light source that would do this job quite as well as the electroluminescent lamp.

In some applications phosphorescence is required of the powder and it is possible to accelerate the rate of decay by heating the powder. Take a photographic negative and behind this place a sheet of phosphorescent material glowing brightly after activation. Now shine on the negative heat radiation : this penetrates through the clear portions of the negative more than through those with the silver deposit, and the clear portions lose their light quicker because of the accelerated decay. Thus when the negative is removed the phosphorescent sheet has behaved as does a sheet of bromide paper, and we have on it a positive. Normally we see pictures of this type (and sometimes of very good photographic quality) when the fluorescent material is excited by electron bombardment in the vision tubes of television sets.

Low pressure mercury fluorescent lamp

One of the most important uses of solid luminescence is that involved in the low pressure mercury fluorescent lamp, a major contribution of the lamp engineer first introduced in the late 1930's. By now the lamp has established itself as probably the most valuable general lighting source available. The basic light-producing process is that of solid luminescence, for the discharge itself contributes very little luminous radiation. The energy conversion is electrical energy to ultra violet energy to luminous energy, the latter via the phosphor. Basically it is very much as when first designed, but changes in detail have brought about considerable improvements. Fig.14 shows the changes of life and efficiency that have occurred since 1940. In addition, the lamp is now a great deal more acceptable both as regards colour, starting behaviour and the range of sizes available.

Although the number of tungsten filament lamps bought each year greatly exceeds the number of fluorescent, if one takes into consideration the higher efficiency and longer life of the fluorescent lamp and speaks not of quantities of lamps but of lumen-hours (which is what we buy lamps for), then the lumen-hours of fluorescent lamps now sold each year exceeds the lumen-hours of tungsten.

The fluorescent lamp costs more than the filament lamp to instal. The total cost of the lighting installation in a modern building is an appreciable item. But so also are lifts, air conditioning, staff canteens, etc. Light generation by means of solid luminescence is part of, and fittingly takes its place, in, the country's rising standard of living. The fact is that it has only one major disadvantage ! Lamps utilising it are bulky. The light output per foot is low. In the most favourable use of the tubular fluorescent lamp it emits not quite 1,000 lumens per foot. Compare this, for example, with what could be obtained from a closely packed row of small-bulb 150-watt incandescent lamps, of something about the same size but with a light output approximately seven times as great. It is true that the filament lamps would consume nearly 40 times the power and would last only one-fifth (at the most) of the life of the fluorescent lamp. Nevertheless it is very desirable to be able to get more light from less bulk. If one puts in more watts per foot, the

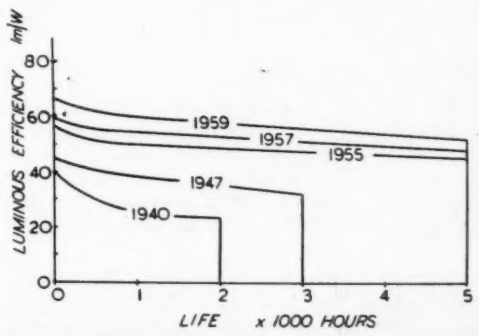


Fig. 14. Performance improvement in fluorescent lamps. (Based on the 80-watt lamp, daylight colour 1940-55, warm white colour 1957-59.)

efficiency falls and the life shortens. A very important problem, therefore, currently interesting lamp engineers is the generation of light using the solid luminescent process in a more concentrated way than we at present know how to do. The work separates into two broad paths.

In one we want an answer to the question—how can phosphors be made or modified so that, under the conditions of high loading, good lumen-maintenance is still obtained? This means that the causes of deterioration must be discovered and if possible eliminated, and a great deal of study is being devoted to this matter. A solid luminor is a substance of high purity with carefully controlled impurity centres. If, during manufacture, one includes in its structure the wrong kind of impurity centres, it is not such a good material. It would, therefore, be surprising if there were not some deterioration of a phosphor for it is exposed, under conditions conducive to adsorption, to the gases and vapours used deliberately and the impurities such as hydrogen, oxygen, carbon, sodium, that find their way into the lamp. These will have a variety of effects all probably tending to cause a reduction with time in lumen output. We can undoubtedly expect to progress in this direction, for an understanding of what is happening is being built up.

The other path concerns the physics of production of ultra-violet light. How can the production of ultra-violet light be maintained in high-loading lamps? To a great extent the physics of the production of ultra-violet from mercury vapour is the same as the production of yellow light from sodium vapour. Maximum ultra-violet emission is secured at high electron temperatures and this means a low gaseous and vapour pressure and a high surface/volume ratio. The number of mercury vapour atoms must be controlled by controlling the temperature. Lamps have been designed to keep the mercury vapour pressure right and without loss of efficiency. Thus we have an 80-watt lamp size running at 125 watts, and 80 watts being taken by a 4 ft. 1 in. diameter tube instead of the normal 5 ft. 1½ in. diameter tube. In one American high loading lamp the envelope has been shaped by corrugating to secure a favourable space factor. These are steps in the right direction, but lamp designers would like to go much further.

The most noteworthy progress that the lamp engineer would welcome, apart from some discovery of a new light producing process, is to know how to put into existing lamp types more energy, so that the total amount of light obtainable from a given size of lamp is increased. He also would like to know how to obtain this light at a higher efficiency. These are great challenges to technology, and to succeed in solving them the lamp engineer, whose work started empirically and who often had to reach a design by cut-and-try methods, now will have to delve deeper into a study of the complex factors involved.

Fortunately a new technology has developed in recent years that greatly assists the lamp research worker in his studies. I refer to the technology of high speed electronic computation. The number of variables in a lamp discharge tube is so great that the complete theoretical elucidation of the physical processes and the determining of basic conditions for maximum outputs is virtually impossible without the use of a high speed computer. Good use, however, is now being made of this new facility. So that this kind of work can be visualised we have prepared a short length of film. This shows the mathematical labour that has to go into the setting up of the equations that it is desired to solve. Then, after suitable programming, the computer takes the quantities (excitation and ionisation functions, diffusion coefficients, mobilities, etc.) describing the basic physical properties of the gases and works out the characteristics of the discharge (electron temperature, field, energy radiated, efficiency, etc.) and how they vary according to the conditions under which it is operated. While such work in many cases may only serve to show that our previous experimental methods have led lamp engineers to the right designs, it is possible that the deeper understanding thus being obtained, especially when this is coupled with the use of the new materials and techniques, will provide us in the future with very considerably improved lamps.

The lecture was illustrated by models, demonstrations and experiments. A short length of film of a ribbon machine, supplied by Glass Bulbs Ltd., was also shown.

Report of the Council

January 1st—December 31st, 1959

It is with a sense of pride that Council presents its Report for 1959, the Golden Jubilee year of The Society. The many events held in London and in every Centre to celebrate the occasion were most successful. Everywhere the prestige of The Society has been enhanced, the value of its work recognised and the cause of good lighting furthered.

It was a particularly happy coincidence that during this Golden Jubilee year H.R.H. The Duke of Edinburgh accepted The Society's invitation to become its first Honorary Fellow.

The activities planned by the Jubilee Committee under the chairmanship of Mr. A. G. Penny were spread over the whole year and over the area of every Centre and Group so that as many people as possible had their attention drawn to the benefits they could derive from good lighting.

Most of the activities were organised in association with other organisations, the members of which were invited to attend or participate in the exhibitions, displays, lectures and conferences initiated by the Jubilee Committee and its sub-committees throughout the country and in the South African Centre at Johannesburg.

Exhibitions, displays, floodlighting, etc., were sponsored or supported by The Society in Birmingham, Cardiff, London, Glasgow, Leeds, Nottingham, Bristol, Manchester, Leicester, Liverpool, Leamington and Johannesburg. Excluding attendances at exhibitions which were not wholly devoted to lighting the total attendance at exhibitions and displays exceeded 100,000.

It is not possible to refer to all the exhibitions in detail but mention should be made of those in Glasgow with nearly 50,000 visitors, Birmingham with 25,000 and Manchester with 9,000. The exhibition in Cardiff was the first to be held in the new Industrial Gallery of the National Museum of Wales. The display at Johannesburg was repeated at the University of Witwatersrand. The floodlighting of Liverpool Cathedral especially deserves mention as an example of industry collaboration involving manufacturers, wholesalers, contractors, the Electricity Board, the British Lighting Council and the Corporation of the City of Liverpool. Over 90 kw of lighting was installed.

In addition to the normal lecture programme for members, special lectures were organised in many of the large centres of population. The total attendance at these lectures was many thousands. They included a series of four lectures given in London in October by eminent scientists and the very successful Swan Anniversary Lecture delivered in Newcastle by Dr. J. N. Aldington which attracted wide attention to the Society. The normal programme of lectures to school children was enlarged during the year and over 100 lectures were given including 45 in Liverpool to 4,000 children, and in Sheffield and Nottingham to 2,500 and 2,000 children respectively.

Conferences for members and others already having some interest in lighting were arranged at Cardiff, Southport, Manchester, York, Nottingham, Bristol, Peebles, London, Bradford. In London a three-day tour was arranged for delegates en route to the C.I.E. meeting in Brussels and was attended by 77 visitors from 20 countries.

The many special functions organised throughout the country received remarkable publicity through the national and local Press, radio and television, and brought the work of The Society to the knowledge of very large numbers of people.

The outstanding success of the celebrations was made possible by the great amount of time and effort given liberally by very many members and Council accords to them its warmest thanks. The Society owes an especial debt to Mr. C. C. Smith, the immediate Past-President, to Mr. A. G. Penny, the Chairman of the Jubilee Committee, and to Mr. G. F. Cole, the Secretary. Council also acknowledges the generous support given by the lighting industry which made possible the large scale of the celebrations.

Council decided to commemorate the Golden Jubilee of The Society by instituting the award of the I.E.S. Gold Medal for outstanding services to the cause of lighting and as reported later was able to make the first award during Jubilee year.

The general work of The Society has continued with vigour. Particular attention has been directed by Council to improving the administrative efficiency and staffing of headquarters and close attention is being given to future policy and organisation in the light of current trends in social life and the requirements of the profession.

It is most encouraging that the upward move in membership noted in the last Report has been well maintained.

During the year Council agreed to the creation of a new Centre at Kingston-upon-Hull, but against this must be set the demise of the Gloucester and Cheltenham Centre. The difficulty of serving members living in parts of the country distant from large centres of population is being studied.

It has been possible during this year for members of Council travelling abroad to make contact with overseas members and in particular to visit and address the South African Centre. Council records its pleasure at being able to receive in this country many overseas members.

Finally Council would thank the Honorary Officers of The Society and the members of committees in London and the Centres for the service they have given.

(1) Membership

(1.1) General

The membership of The Society increased by 73 during the year and the number of Sustaining Members by two. This increase is very similar to that of the previous year and confirms that the earlier downward trend has been reversed. The great interest shown in the Jubilee activities of The Society indicates that the point of saturation has not yet been reached and Council urges all Centres to continue their search for new members. The gains that can be secured with enthusiasm and persistence have been demonstrated during these last two years both in London and in several Centres.

Details of the membership at December 31, 1959, are given in Table 1 and Appendix B records the changes in membership since 1950.

(1.2) Honorary Fellowship

Council records with great pleasure that His Royal Highness The Duke of Edinburgh, K.G., K.T., has accepted its invitation to become the first Honorary Fellow of The Society. It is hoped that presentation of the certificate of Honorary Fellowship will be made at a meeting of The Society in the near future.

(1.3) Honorary Membership

Council has elected Mr. A. W. Beuttell to Honorary Membership of The Society in recognition of his contributions to the science of lighting and of his great services to The Society in its early years.

(1.4) Fellowship and Diploma Membership

During 1959 Dr. F. A. Benson and Professor J. G. C. Weber were elected Fellows of The Society. Council also approved the election of three new Diploma Members.

(1.5) I.E.S. Gold Medal

The first award of the I.E.S. Gold Medal was made to Dr. J. W. T. Walsh for his outstanding services to lighting both nationally and internationally. The Medal was presented to Dr. Walsh on October 13 at the opening sessional meeting of The Society.

(1.6) Leon Gaster Memorial Premium

The Leon Gaster Memorial Premium for the published contribution of highest merit during 1958/59 was awarded to Dr. R. G. Hopkinson and Mr. J. Longmore for their paper " The Permanent Supplementary Artificial Lighting of Interiors."

(1.7) Honours conferred on members

Council noted with pleasure that the following honours were conferred on members during 1959 :—

O.B.E.—H. C. Weston, Honorary Member, Past-President, and former Honorary Secretary.

M.B.E.—W. E. Rawson-Bottom, Fellow and Vice-President.

(1.8) Deaths

Council received with regret news of the deaths of several members. Among them were Professor Emeritus J. T. MacGregor-Morris, Professor J. G. C. Weber, Mr. C. R. Bicknell and Mr. C. J. Chisholm.

Professor MacGregor-Morris was one of the original members of The Society and served it with distinction in many capacities. He was elected President in 1940-41 and an Honorary Member in 1952.

Mr. Bicknell was a most active member of Council for many years and had served as a Vice-President and as Honorary Editor of the Transactions.

Though Professor Weber had been a member of The Society for only a few years he had made many contributions to lighting which had been recognised by his election as a Fellow only a few weeks before his death at an early age.

Mr. Chisholm was a past-chairman of the Sheffield Centre and had made many contributions to the practice of street lighting.

(2) Society Activities

(2.1) Meetings

The sessional meetings of The Society in London

Membership
(As at December 31, 1959)

	Fellows	Diploma Members	Corporate Members	Students	TOTAL	Sustaining Members
London ...	99	100	590	40	829	65
Centres:						
Bath & Bristol	4	6	67	2	79	2
Birmingham ...	8	21	182	7	218	24
Cardiff... ...	3	7	37	—	47	1
Edinburgh ...	3	7	29	—	39	3
Glasgow ...	4	17	42	3	66	7
Kingston-upon-Hull... ...	—	1	51	4	56	3
Leeds	4	16	99	12	131	5
Leicester ...	3	8	42	—	53	1
Liverpool ...	2	7	113	2	124	8
Manchester ...	4	15	116	2	137	13
Newcastle upon Tyne ...	4	7	84	—	95	4
Nottingham ...	2	4	60	6	72	1
Sheffield ...	4	4	50	2	60	2
South Africa ...	—	3	59	—	62	14
Groups:						
North Lancs. ...	2	3	34	—	39	1
Stoke-on-Trent	—	—	17	1	18	—
Swansea ...	—	—	19	—	19	—
Tees-side ...	—	—	27	2	29	—
Overseas ...	11	18	247	—	276	2
TOTAL ...	157	244	1,965	83	2,449	156

have been very well attended, the average number present being considerably larger than in 1958. Council believes that this improvement is a result of the high standard now set by the Papers Committee for contributions to sessional meetings, but is aware of the difficulties which face the Committee in obtaining sufficient papers of the required quality. It has instructed the Committee to consider the pattern of activities in the future, and encourages the Papers Committees of the Centres to do likewise ; some Centres, it is noted, are already engaged in this task. It is not to be expected that a single policy will serve equally well the needs of all Centres ; local circumstances and facilities must have a considerable formative influence.

An additional sessional meeting of The Society was arranged on July 8 to hear Dr. H. R. Blackwell and Mr. C. L. Crouch, of the United States, describe the basis and application of the new illumination values recently adopted by the American I.E.S., and Dr. A. Dresler speak on the new Australian Code for the Artificial Lighting of Buildings. A large audience was present.

Following enquiries regarding suitable places for London sessional meetings, Council agreed that they should be held at the Federation of British Industries, with the exception of the opening meeting and the Trotter-Paterson lecture which will, as far as possible, be held at the Royal Institution.

(2.2) Trotter-Paterson Lecture

The fifth Trotter-Paterson Memorial Lecture was given by Professor Sir Solly Zuckerman, C.B., F.R.S., at the Royal Institution on February 16 ; Sir Solly Zuckerman's subject was " Light and Living Matter." Two hundred and twenty members and visitors were present—the largest attendance to date at this lecture.

(2.3) A.G.M. Lecture

During recent years the Papers Committee has sought to make the lecture which follows the Annual General Meeting of The Society (when held in London) a complement to the Trotter-Paterson Lecture. As the latter is related to the science of lighting, so a relation has been sought in the A.G.M. lecture to the art of lighting. The 1959 lecture was held at the National Gallery when an extensively illustrated address was given by Sir Phillip Hendy, Director of the National Gallery, on "Light and Pattern in Painting." Again there was a very large attendance.

(2.4) Annual dinner

The Annual Dinner held at the Criterion Restaurant on February 9 was the Golden Jubilee Commemoration Dinner of The Society. It was attended by 450 members and guests and the speeches were relayed to gatherings in all Centres, including the South African Centre, a commentary being given by Mr. W. R. Stevens.

The toast of The Society was proposed by The Very Reverend A. C. Don, K.C.V.O., the President replying. Toasts to "Science," "Art," and "Industry" were proposed by Dr. G. B. B. M. Sutherland, F.R.S., Sir Charles Wheeler, K.C.V.O., and Sir Leslie Gamage respectively. The toast of "The Guests" was proposed by Dr. J. W. T. Walsh, O.B.E., Past-President, and the response made by The Right Worshipful Councillor David Cobbold, J.P., Mayor of Westminster.

(2.5) Summer meeting

Arrangements for the Summer Meeting to be held at Harrogate from May 15-18 are nearing completion. The programme has been modified from that of earlier meetings to give greater opportunities for informal discussion on matters of current importance to lighting engineers. Council hopes that the meeting will be well supported.

(2.6) Centres

The year has been one of great activity in al Centres. The special Jubilee lectures, exhibitions and displays of lighting have done much to bring The Society before the general public in all parts of the country.

Council notes with warm approval the continuing practice in some Centres of holding one or more meetings in neighbouring towns and would encourage other Centres to develop this practice wherever possible.

Comment has already been made on the establishment of a new Centre at Kingston-upon-Hull and Council is confident that the Centre will continue to grow in strength and influence. It regrets the necessity which arose to close the Gloucester and Cheltenham Centre but had to recognise that the number of members in this area of the country was too small to support the activities of a Centre.

Meetings of the Centres Joint Committee were held during 1959 in Nottingham and London and useful interchanges of views took place. It is hoped that the reorganisation of headquarters staff will enable the Secretary to visit Centres more frequently, to give them greater assistance and to improve liaison between Centres and headquarters.

The Liverpool Centre extended an invitation to Council to hold its April meeting in Liverpool and to attend the Civic Reception offered by the Lord Mayor and Corporation of the City to The Society. Council accepted the invitation with pleasure and much appreciated the further gesture of the City Corporation in entertaining the Council to lunch the following day.

At the close of the 1958/59 Session the following Honorary Secretaries of Centres relinquished office : Mr. F. Jackson (Leicester Centre), Mr. H. L. Roston (South African Centre), Mr. R. P. Wingate (Newcastle-upon-Tyne Centre). Council records its warm thanks to them for the services they have given The Society during their period of office.

(3) Society Publications

In spite of difficulties and delays created by the strike in the printing industry, the full number of Transactions has been published and also the first two Monographs.

The response to the publication of highly technical papers in Monograph form has been most encouraging and the number of standing orders received has ensured that the venture will be financially self-supporting.

As indicated in Section 4 of this Report, none of the several investigations being undertaken by the Technical Committee was completed during 1959 and consequently no Technical Reports were issued during the year. It is, however, expected that three such Reports will be published in 1960.

Council would draw the attention of members to the facilities of the library at headquarters and invites them to consult it whenever necessary. Attention is being given to this particular service The Society offers and it is hoped that more information will be made available to members in the near future so that the usefulness of the library can be increased.

Council has noted with appreciation the considerable space given to the Jubilee activities of The Society in *Light and Lighting* and records its thanks to The Lighting Press Ltd.

(4) Technical Investigations

The various investigations initiated by the Technical Committee have been developed and new investigations started during the year.

(4.1) I.E.S. Code

Work on the revision of the I.E.S. Code for Lighting in Buildings has progressed steadily throughout the year, particular attention being directed to the basis for illumination recommendations and to evaluation of glare. It is expected that the new Code will be published at the beginning of 1961.

(4.2) Lighting design data

Following the discussion at a sessional meeting of the interim report on the calculation of coefficients of utilisation, the panel has been completing the comprehensive data and preparing a simplified scheme using acceptable approximations. It is hoped that a Technical Report containing the data will be published in the first half of 1960.

(4.3) Lighting of building sites and works of engineering construction

The work on this subject has reached an advanced stage and publication of the Technical Report is expected during 1960.

(4.4) Area lighting

The panel dealing with area lighting under the Chairmanship of Mr. Imrie-Smith has begun its work and is now collating data for inclusion in a Technical Report.

(4.5) New investigations

Work has been commenced under the direction of Mr. H. C. Weston and Dr. Weale to prepare a Technical Report on "Lighting for Older Workers."

(4.6) Technical Report No. 1

This report, issued at the end of 1958 and dealing with lighting in hazardous and corrosive situations, has been well received and sales have been greater than expected. It is, however, somewhat disappointing that only one Centre has seen fit to include discussion of the Report in its programme, as these Technical Reports provide means of bringing this work of The Society to the notice of interested parties throughout the country.

(4.7) Liaison with universities and technical colleges

It is most encouraging to report that research projects related to lighting have been started during this year at the University of Sheffield under the direction of Dr. F. A. Benson and at the Northampton College of Advanced Technology under Dr. C. A. Padgham. It is hoped that these projects represent the start of a greater interest in lighting matters within the universities and colleges.

(5) Education

Council has noted with great concern the fall in the numbers taking the City and Guilds examinations in illuminating engineering as a prelude to applying for Diploma Membership. Council believes that unless this position is recognised and rectified there is danger that lighting as a profession may effectively cease in the not too distant future. It has therefore instructed the Education Committee to review this side of its work as part of the investigation into the future policy of The Society and to treat the matter as one of urgency.

The Education Committee is reviewing the syllabus of the City and Guilds examination and is also considering possible approaches to meet the problems of students in the provinces where numbers are too small for classes in illuminating engineering to be held.

(6) Headquarters Staff and Administration

As indicated in the last Annual Report, Council has been concerned for some time about the inadequate headquarters staff of The Society and its poor office accommodation. On the recommendation of the General Purposes Committee it instructed Urwick, Orr and Partners to investigate the existing organisation and to prepare recommendations. This was done in July and the following actions have since been taken :—

(i) A new agreement has been concluded with the Secretary.

(ii) Mr. B. R. Lovell has been appointed to act as Assistant Secretary and Office Manager ; his duties commenced in August.

(iii) The office duties have been re-allocated and new staff engaged.

(iv) The office premises have been modernised and redecorated to provide more efficient and pleasant accommodation. The extent of this modernisation was, however, limited as it was recognised that new premises may have to be sought when the present lease expires in March, 1963, in view of the rebuilding scheme for the area which has already been started.

BALANCE SHEET 31st DECEMBER, 1959

1958 £		£ s. d.	£ s. d.
	Capital Account:		
	Balance at 31st December, 1958 ..	8,618 1 1	
	Add Reserve for Special Expenses ..	91 7 8	
	Reduction in provision to reduce Investments to market value ..	9 0 0	
		8,718 8 9	
	Less Transfer to Jubilee Fund £1,500 0 0		
4,854	Excess of Expenditure over Income for the year .. 114 18 11		
1,278			
3,576		1,614 18 11	
8,618			7,103 9 10
91	Reserve for Special Expenses		
991	Creditors		1,043 17 0
9,700			8,147 6 10
	Jubilee Fund:		
	(per Receipts and Payments Account		
2,515	attached)..		615 10 6
	Other Funds:		
	(per Receipts and Payments Accounts attached):		
	Leon Gaster Memorial	251 11 4	
	Trotter-Paterson Memorial Lecture ..	361 19 6	
	John S. Dow Legacy	2,426 4 0	
		3,039 14 10	
	Held on behalf of National Illumination Committee	348 2 8	
3,361			3,387 17 6
	A. W. Gostt (*Hon. Treasurer*).		
3,361	W. E. Harper (*Hon. Secretary*).		
£15,576			£12,150 14 10

1958 £		£ s. d.	£ s. d.
	Quoted Investments, at Cost:		
	£2,320 14s. 7d. 3½% War Loan	2,364 3 6	
	£500 3% British Transport Guaranteed Stock 1978/88	488 4 6	
	£500 3% Savings Bonds 1955/65 ..	501 15 3	
	£1,000 3% Savings Bonds 1965/75 ..	1,000 0 0	
	£500 4½% Conversion Stock 1962 ..	500 0 0	
4,854		4,854 3 3	
1,278	*Less* Provision to reduce to Market Value	1,269 3 3	
3,576			3,585 0 0
	Unquoted Investments, at Cost:		
	£250 5% Defence Bonds	250 0 0	
	£1,250 4½% Defence Bonds	1,250 0 0	
	£100 3½% Defence Bonds	100 0 0	
	£500 Abbey National Building Society—Deposit	500 0 0	
4,350			2,100 0 0
167	Debtors		43 5 5
1,607	Balance at Bank and Cash in Hand ..		2,419 1 5
9,700			8,147 6 10
	Jubilee Fund:		
2,515	Balance at Bank		615 10 6
	Other Funds:		

	Investments £ s. d.	Balance at Bank £ s. d.	
Leon Gaster Memorial ..	236 13 2	14 18 2	
Trotter-Paterson Memorial Lecture	350 0 0	11 19 6	
John S. Dow Legacy ..	2,046 5 0	379 19 0	
	2,632 18 2	406 16 8	
Held on behalf of National Illumination Committee	304 8 6	43 14 2	
3,361	2,937 6 8	450 10 10	3,387 17 6
£15,576			£12,150 14 10

Auditors' Report. We have audited the above Balance Sheet and annexed Income and Expenditure Account and have obtained all the information and explanations which we considered necessary. Proper books have been kept and the accounts, which are in agreement therewith, comply with the requirements of the Companies Act, 1948.

In our opinion the Balance Sheet and Income and Expenditure Account give respectively a true and fair view of the state of the Society's affairs at 31st December, 1959, and of the deficit for the year to that date.

Dated this 26th day of January, 1960.

3, Robert Street, Adelphi, W.C.2.

Robert J. Ward & Co.,
Chartered Accountants.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st DECEMBER, 1959

1958 £		£ s. d.	£ s. d.
	Administration Expenses:		
2,994	Salaries and National Insurance	3,304 18 4	
110	Staff Superannuation Scheme	144 15 10	
507	Rent and Rates	507 1 0	
75	Lighting and Heating	55 19 10	
118	Telephone	128 3 0	
654	Printing and Stationery	599 15 6	
437	Postage	472 8 9	
89	Travelling Expenses	191 14 6	
—	Professional Fees	157 10 0	
—	Redecorations and Refurnishing	624 15 10	
248	Sundry Office Expenses	395 0 6	
5,232			6,582 3 1
296	Meetings in London		266 0 6
1,662	Expenditure of Centres and Groups		1,670 13 10
37	Audit Fee		36 15 0
7,227			8,555 12 5
1,988	Cost of Printing *Transactions*, Reprints, Technical Reports, etc.		1,421 16 7
116	Expenditure on Summer Meeting, *less* Sale of Tickets		—
3	Expenditure on Industrial Lighting Conference, *less* Sale of Tickets		—
20	Transfer to Leon Gaster Memorial Fund		—
	The Lighting Press Ltd.:		
	Cost of *Light and Lighting*	2,220 16 4	
	Less Contribution towards Administration Expenses	500 0 0	
1,835			1,720 16 4
62	Contributions to Kindred Societies		62 9 0
11,251			11,760 14 4
38	Balance, being excess of Income over Expenditure		—
£11,289			£11,760 14 4

1958 £		£ s. d.
10,252	Subscriptions and Fees	10,382 12 6
688	Sales of Publications	931 3 7
313	Interest on Investments	301 18 10
34	Interest on Bank Deposit	20 0 6
—	Premium on Redemption of Investments	10 0 0
2	Premium on Conversion of Investments	—
—	Balance, being excess of Expenditure over Income	114 18 11
£11,289		£11,760 14 4

RECEIPTS AND PAYMENTS ACCOUNTS FOR THE YEAR ENDED 31st DECEMBER, 1959

Leon Gaster Memorial Fund

	£ s. d.		£ s. d.	£ s. d.
Balance at 1st January, 1959	254 0 4	Premiums Paid		10 10 0
War Loan Interest	8 1 0	Balance at 31st December, 1959:		
		Cash at Bank	14 18 2	
		£230 3½% War Loan at Cost	236 13 2	
		(*Market Value £150*)		251 11 4
	£262 1 4			£262 1 4

Trotter-Paterson Memorial Lecture Fund

	£ s. d.		£ s. d.	£ s. d.
Balance at 1st January, 1959	375 19 6	Lecture Fee		26 5 0
Defence Bond Interest	12 5 0	Balance at 31st December, 1959:		
		Cash at Bank	11 19 6	
		£350 3½% Defence Bonds at Cost	350 0 0	
				361 19 6
	£388 4 6			£388 4 6

John S. Dow Legacy Fund

	£ s. d.		£ s. d.	£ s. d.
Balance at 1st January, 1959	2,357 2 6	Balance at 31st December, 1959:		
Interest on Investments	69 1 6	At Cost:		
		£916 11s. 1d. 3½% War Loan	876 5 0	
		£500 3% Savings Bonds 1955/65	492 10 0	
		£500 3% Savings Bonds 1960/70	477 10 0	
		(*Market Value £1,474*)		
			1,846 5 0	
		£200 3½% Defence Bonds	200 0 0	
		Cash at Bank	379 19 0	
				2,426 4 0
	£2,426 4 0			£2,426 4 0

National Illumination Committee Fund

	£ s. d.		£ s. d.	£ s. d.
Balance at 1st January, 1959	374 2 1	Paid to National Illumination Committee of Great		
War Loan Interest	10 10 0	Britain		36 9 5
		Balance at 31st December, 1959:		
		Cash at Bank	43 14 2	
		£300 3½% War Loan at Cost	304 8 6	
		(*Market Value £196*)		348 2 8
	£384 12 1			£384 12 1

RECEIPTS AND PAYMENTS ACCOUNTS FOR THE YEAR ENDED 31st DECEMBER, 1959—*continued*

Jubilee Fund

	£	s.	d.	£	s.	d.		£	s.	d.
Balance at 1st January, 1959:							Salaries and Incidental Expenses	171	10	6
Donations Received	1,802	8	0				Publicity	630	0	7
do. Special Contribution re C.I.E. Delegates	400	0	0				President's Reception	818	4	2
Sale of Dinner Tickets	531	12	3				Commemoration Dinner	1,327	5	8
Transfer from International Illumination Congress Fund	116	2	0				Commemoration Lectures	175	6	6
	2,850	2	3				Stand at Association of Supervising Electrical Engineers Exhibition	1,050	0	0
	334	16	1				Grants to Provincial Centres	907	11	3
							Tour of C.I.E. Delegates	801	5	9
Less Salaries and Incidental Expenses				2,515	6	2		5,681	4	5
				67	7	0	Balance at 31st December, 1959	615	10	6
Donations Received										
do. Special Contribution re C.I.E. Delegates				247	0	0				
do. Special Contribution re A.S.E.E. Stand				750	0	0				
Sale of Dinner Tickets				435	17	9				
Sale of Reception Tickets				781	4	0				
Transfer from General Account				1,500	0	0				
				£6,296	14	11		£6,296	14	11

(v) The office machinery, filing and storage systems have been brought into line with modern practice.

While Council is confident that these actions have considerably strengthened the administrative efficiency of headquarters and lightened the executive responsibility previously resting solely on the Secretary, it is aware that much still remains to be done. The organisation for the production of publications calls for improvement and the likely need for new premises will soon demand urgent consideration. These matters are being considered as part of the future policy of the Society.

Council expresses its indebtedness to the Secretary for the great service he has given to The Society throughout this arduous and difficult year and also records its thanks to the staff for their help.

(7) Finance

The Society's expenditure for 1959 exceeded its income by a small amount. In spite of savings made on several items total expenses were heavier than estimated due largely to the implementation of The Society's policy concerning additional staff and better office accommodation.

It must, however, be pointed out that the full extra cost of implementing the new policy will be apparent only during the coming year and it is expected that expenditure in 1960 will considerably exceed receipts. Council has considered carefully the possible future trend in the finances of The Society and has instructed the Honorary Treasurer and the General Purposes Committee to investigate the matter in detail and to prepare recommendations in line with the future general policy of The Society.

(8) Future Policy

Council has charged the General Purposes Committee to review all aspects of The Society's work with the assistance of the appropriate standing committees and to prepare a detailed report. The Committee has presented a preliminary memorandum to Council but the full investigation is likely to take several months.

Council is confident that in spite of evident difficulties which lie before The Society, policies will be evolved which will enable its work to be continued with growing effectiveness in the future.

H. G. CAMPBELL, *President.*

W. E. HARPER, *Hon. Secretary.*

Appendix 1

(a) Officers and Members of Council

President: H. G. Campbell. *Vice-Presidents:* F. A. Benson, A. H. Olson, W. E. Rawson-Bottom, W. S. Stiles, D. L. Tabraham. *Hon. Secretary:* W. E. Harper. *Hon. Treasurer:* A. W. Gostt. *Hon. Editor of Transactions:* H. Hewitt.

Past-Presidents: The Rt. Hon. The Earl of Mount Edgcumbe, A. W. Beuttell, A. Cunnington, S. English, F. C. Smith, W. J. Jones, E. Stroud, H. C. Weston, J. W. T. Walsh, J. N. Aldington, J. M. Waldram, L. J. Davies, W. J. Wellwood Ferguson, W. R. Stevens, J. G. Holmes, E. C. Lennox, A. G. Higgins, E. B. Sawyer, C. C. Smith.

Ordinary Members: A. E. Bird, B. M. Cobbe, J. B. Collins, P. H. Collins, J. G. Christopher, C. Dykes Brown, E. S. Evans, A. E. Gaster, J. T. Grundy, J. W. Howell, A. H. Nash, C. A. Padgham, A. O. Johnston, J. S. McCulloch, A. G. Penny, A. Roberts, T. Roberts, H. R. Ruff, W. Imrie-Smith, W. T. F. Souter, D. A. Strachan, J. W. Strange, R. L. C. Tate, A. Wilcok.

Representatives of Centres: The Chairmen of Centres. (See (b) below.)

(b) Chairmen and Secretaries of Centres

CENTRE	CHAIRMAN	HON. SECRETARY
Bath and Bristol	J. H. Munns	T. O. Pettit
Birmingham	J. R. Yeates	R. C. Willdey
Cardiff	A. J. Dalton	G. J. Everett
Edinburgh	G. R. N. Chalmers	C. Couper
Glasgow	J. Stewart	A. M. Rankin
Kingston-upon-Hull	T. H. Bradley	P. J. Price
Leeds	A. J. Johnson	K. J. Goddard
Leicester	E. W. Freeman	A. Y. Johnson
Liverpool	W. J. Forster	N. Blackman
Manchester	E. J. Smith	E. Axon
Newcastle upon Tyne	B. Wray	N. Maxwell
Nottingham	D. R. M. Hornsey	G. C. Small
Sheffield	V. Loupart	E. G. R. Taylor
South Africa	H. L. Roston	L. O. Foster

(c) Members of Standing Committees

GENERAL PURPOSES COMMITTEE
H. G. Campbell (Chairman), C. C. Smith, F. A. Benson, A. H. Olson, W. E. Rawson-Bottom, W. S. Stiles, D. L. Tabraham, A. W. Gostt, W. E. Harper, A. J. Dalton, E. J. Smith.

Sub-Committees of the General Purposes Committee
Summer Meeting (1960): J. G. Christopher (Chairman), N. Boydell, C. Dykes Brown, E. S. Evans, A. H. Nash, A. H. Olson, C. J. W. Scott, A. H. Young.
Publicity and Membership: J. G. Holmes (Chairman), G. Cole, J. J. Davies, D. W. Durrant, D. E. Mutch, A. H. Nash, G. Reeves, E. B. Sawyer, W. Robinson.

TECHNICAL COMMITTEE
W. T. Souter (Chairman), N. Boydell, B. M. Cobbe, A. W. Gostt, W. E. Harper, P. Hartill, J. G. Holmes, R. G. Hopkinson, W. Imrie-Smith, J. S. McCulloch, W. E. Rawson-Bottom, W. Robinson, A. Roberts, H. R. Ruff, E. B. Sawyer, J. W. Strange, D. L. Tabraham, J. M. Waldram, H. C. Weston.

PAPERS COMMITTEE
H. H. Ballin (Chairman), J. B. Collins, D. H. Holloway, H. E. Bellchambers, D. A. Strachan, W. S. Stiles, R. L. C. Tate, T. Roberts, H. C. Weston.

EDUCATION COMMITTEE
C. A. Padgham (Chairman), F. A. Benson, P. H. Collins, A. G. Higgins, R. R. Holmes, L. F. Needham, E. B. Sawyer, D. L. Tabraham.

CENTRES JOINT COMMITTEE
The Committee consists of the President, Vice-Presidents, the Honorary Officers of The Society and the Chairman and the Honorary Secretary of each Centre.

AWARDS JUDGING COMMITTEE
H. H. Ballin, C. Dykes Brown, J. B. Collins, H. Hewitt, J. G. Holmes, A. G. Penny, R. L. C. Tate.

Appendix 2

Membership of the Society, 1949-1959

Centre or Group	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
London	668	661	710	739	735	754	822	805	786	794	829
Bath & Bristol	77	70	70	61	65	53	58	55	50	60	79
Birmingham	243	239	251	246	243	233	230	224	206	224	218
Cardiff	69	74	74	72	70	66	68	69	57	51	47
Edinburgh	48	45	45	44	41	46	44	41	36	37	39
Glasgow	74	72	80	79	75	72	72	74	59	63	66
Gloucester & Cheltenham	35	44	42	40	37	33	33	30	23	19	—
Kingston-upon-Hull ...	—	—	—	—	—	—	—	—	—	—	56
Leeds	117	116	134	121	115	209	207	205	187	181	131
Leicester	48	45	41	36	39	34	35	36	38	51	53
Liverpool	114	117	123	122	119	113	112	114	103	116	124
Manchester	147	163	143	145	139	139	148	152	140	154	137
Newcastle upon Tyne ...	100	101	104	96	89	88	98	95	89	98	95
Nottingham	76	72	77	75	77	75	76	79	70	69	72
Sheffield	68	65	63	69	67	70	68	63	57	57	60
South Africa	—	—	—	—	—	50	57	63	66	63	62
N. Lancs.	—	—	44	56	54	52	50	41	38	32	39
Stoke	24	31	30	29	23	22	23	25	17	16	18
Swansea	24	26	21	22	20	20	19	22	20	18	19
Tees-side	27	24	23	20	22	21	26	21	20	13	29
Bradford	34	33	34	33	31	—	—	—	—	—	—
Exeter	31	28	25	20	—	—	—	—	—	—	—
Huddersfield	37	37	40	37	36	—	—	—	—	—	—
Sussex	28	29	27	31	34	35	—	—	—	—	—
Overseas	146	160	178	202	208	202	225	245	240	260	276
TOTAL	2,235	2,252	2,379	2,395	2,339	2,387	2,471	2,459	2,302	2,376	2,449

Appendix 3

I.E.S. Representatives on Outside Committees

NATIONAL ILLUMINATION COMMITTEE	G. F. Cole, J. G. Holmes, L. H. McDermott, C. C. Smith, J. M. Waldram
COUNCIL FOR CODES OF PRACTICE	W. Robinson
Codes of Practice Committee for Buildings	J. G. Holmes
Codes of Practice Committee for Electrical Engineering	W. R. Stevens
PARLIAMENTARY AND SCIENTIFIC COMMITTEE	W. E. Harper
CITY AND GUILDS OF LONDON INSTITUTE ADVISORY COMMITTEE ON ILLUMINATING ENGINEERING	W. R. Stevens
INSTITUTION OF ELECTRICAL ENGINEERS :	
Panel to formulate recommendations of good practice for adequate wiring of buildings	D. L. Tabraham
COMMITTEES OF THE BRITISH STANDARDS INSTITUTION :	
Aircraft Lamps and Lampholders	A. G. Penny
British National Committee of the I.E.C.	J. N. Aldington
Cinematograph Industry Standards Committee	H. C. Weston
Cinematograph Electrical Equipment	S. S. Beggs
Cinema Studio Lighting, Lamps and Fittings	S. S. Beggs
Cinematograph Carbon-Arc Equipment	F. S. Hawkins
Auditorium and Safety Lighting for Cinemas and Theatres	S. S. Beggs
Safety Signs for Cinemas and Theatres	S. S. Beggs
Stage Electrical Accessories	E. E. Faraday

Code of Practice Committee on Street Lighting	E. Stroud, J. M. Waldram
Low Pressure Gas Mantles	F. C. Smith
Metal Windows	G. F. Cole
Illumination Industry Standards Committee	J. M. Waldram, J. G. Holmes, L. H. McDermott, G. F. Cole, C. C. Smith
Nomenclature for Illumination	W. Robinson, G. F. Cole
Photometric Integrators	G. T. Winch
Lighting Fittings	W. T. F. Souter, A. W. Jervis
Diffusing Materials	J. W. T. Walsh
Fittings for Double-capped Tubular Lamps	V. F. Beuttell
Watertight Electric Light Fittings	G. W. S. Levey
Lighting Fittings for Hospitals	Bryan Cross, C. J. King
Flameproof Fittings for Lighting Purposes	J. Studholme
Electric Lamps	W. T. F. Souter
Electric Lamps for Navigation Purposes	A. G. Penny
Tungsten Filament Lamps	A. G. Penny
Discharge Lamps	A. G. Penny
Electric Signs	E. F. Martin
Ultra-Violet Light	A. G. Penny
Co-ordination of Colours for Signal Purposes	J. G. Holmes
Colour Terminology	G. T. Winch
Photographic Electronic Flash Equipment	T. S. Ainsworth
Construction of Road Traffic Signs	F. C. Smith
Photographic Industry Standards Committee	A. W. Gostt
Protection Against Injurious Radiation	H. C. Weston
Tail Lights and Reflex Reflectors for Vehicles	H. F. Stephenson

Appendix 4

Sustaining Members

A.E.I. Lamp & Lighting Co. Ltd.
Head Office, Melton Road, Leicester.

A.E.I. South Africa (Pty.) Ltd.
P.O. Box 7755, Johannesburg, South Africa.

Aladdin Lighting Ltd.
P.O. Box 3491, Johannesburg, South Africa.

Allom Brothers Ltd.
Lombard Road, Merton, London, S.W.19.

Arrow Plastics Ltd.
Arrow Works, Portsmouth Road, Thames Ditton, Surrey.

Atlas Lighting Ltd.
Thorn House, St. Martin's Lane, London, W.C.2.

Aurora Lamps Ltd.
Old Kilpatrick, Glasgow.

Barlow & Young Ltd.
55, Catherine Place, London, S.W.1.

Beadle, T., & Co. Ltd.
3-5, Castle Street, Hull, Yorks.

Beadle Export Co. Ltd., T.
8, Castle Street, Hull, Yorks.

Benjamin Electric Ltd.
Brantwood Road, Tottenham, N.17.

Birmingham City of, Education Dept.
Council House, Margaret Street, Birmingham.

Bolton Corporation Lighting Dept.
Marsden Road, Bolton, Lancs.

British Electrical Development Association, The
2, Savoy Hill, Strand, London, W.C.2.

British General Electric Co. (Pty.) Ltd., The
Magnet House, Corner Loveday and Anderson Street, Johannesburg, South Africa.

British Luma Co-operative Electric Lamp Society Ltd.
Hardgate Road, Glasgow, S.W.1.

British Optical Association
65, Brook Street, London, W.1.

Cartwright, J. T., & Sons Ltd.
195, St. Vincent Street, Glasgow, C.2.

Ceag Ltd.
Queen's Road, Barnsley.

Central Electricity Generating Board
Bankside House, Sumner Street, London, S.E.1.

Chance Bros. & Co. Ltd.
Glass Works, Smethwick, Birmingham.

Cinematograph Exhibitors' Association of Great Britain and Ireland, The
164, Shaftesbury Avenue, London, W.C.2.

Claude Neon Lights of New Zeland Ltd.
91, Hobson Street, Auckland, C.1, New Zealand.

Clegg, E., & Son Ltd.
Shore Mills, Littleborough, Lancs.

Vic Coupland Ltd.
9, Castle Street, Hull.

Courtney, Pope (Electrical) Ltd.
Amhurst Park Works, Tottenham, N.15.

Crompton Parkinson Ltd.
Crompton House, Aldwych, London, W.C.2.

Crossland, R. & A. G., Ltd.
Cartbridge Lane, Walsall, Staffs.

Cryselco Ltd.
Kempston Works, Bedford.

Daleman Ltd., Richard
325/327, Latimer Road, London, W.10.

Davies & Co. Ltd., Hubert
P.O. Box 1386, Johannesburg, South Africa.

Daylight Fixtures Corporation
New Citizen Bank House, Carnic Road, Bombay, 1, India.

Dernier & Hamlyn Ltd.
23, Newman Street, London, W.1.

Docker Bros.
Rotton Park Street, Ladywood, Birmingham, 16.

DOMINEC (PTY.) LTD.
P.O. Box 3269, Johannesburg, South Africa.
DORMAN & SMITH LTD.
Atherton Works, Blackpool Road, Preston, Lancs.
DOWNES & DAVIES LTD.
1-9, Stanley Street, Liverpool, 1.

EASTERN ELECTRICITY BOARD
Whersted, Ipswich, Suffolk.
EASTERN GAS BOARD
Sun Building, Clarenden Road, Watford, Herts.
EAST MIDLANDS ELECTRICITY BOARD
Mapperley Hall, Nottingham.
EDINBURGH CORPORATION OF THE CITY AND ROYAL BURGH OF
City Chambers, Edinburgh, 1.
E.G.S. CO. LTD.
10-12 Trafalgar Street, Newcastle-on-Tyne, 1.
EKCO-ENSIGN ELECTRIC LTD.
Preston House, 45, Essex Street, Strand, W.C.2.
ELECTRICAL COMPONENTS LTD.
Components House, Ludgate Hill and Lionel Street, Birmingham, 3.
ELECTRICITY COUNCIL, THE
Trafalgar Buildings, 1, Charing Cross, London, S.W.1.
ELECTRIC LAMP INDUSTRY COUNCIL
25, Bedford Square, London, W.C.1.
ELECTRIC STREET LIGHTING APPARATUS CO. LTD.
The Foundry, Canterbury, Kent.
ELLISON LTD., GEORGE
Wellhead Lane Works, Perry Barr, Birmingham, 22b.
ENGINEERING & LIGHTING EQUIPMENT CO. LTD.
Sphere Works, St. Albans, Herts.
ERINOID LTD.
96, Piccadilly, London, W.1.
EVANS ELECTROSELENIUM LTD.
Potter Street, Harlow, Essex.
EVER READY CO. (GREAT BRITAIN) LTD.
Hercules Place, London, N.7.

FALKS ELECTRICAL (S.A.) (PTY.) LTD.
P.O. Box 246, Roodepoort, Transvaal, South Africa.
FALK STADELMANN & CO. LTD.
91, Farringdon Road, London, E.C.1.
FIELD & SON LTD., H. W.
Cable Works, Station Road, Harold Wood, Essex.
FOSTER ELECTRICAL SUPPLIES LTD.
Morden Road, S. Wimbledon, London, S.W.19.
FRENCH LTD., B.
Mill Lane, Kidderminster, Worcs.
FULFORD BROWN BROS. (1929) LTD.
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LONDON ELECTRICITY BOARD
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Alliance House, Caxton Street, London, S.W.1.
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MIDLANDS ELECTRICITY BOARD
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NETTLE ACCESSORIES LTD.
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S.L.R. ELECTRIC LTD.
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SMITH & CO. (ELECTRICAL ENGINEERS) LTD., W. H.
12, York Street, Manchester, 2.
HERMAN SMITH SMITHLITE LTD.
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SNEATH LTD., J. G.
Wallwood Street, London, E.14.
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10, Queen's Gardens, Hove, 3, Sussex.
SOUTH OF SCOTLAND ELECTRICITY BOARD
Inverlair Avenue, Glasgow, S.4.
SOUTH WALES ELECTRICITY BOARD
St. Mellons, Cardiff.
SOUTH WESTERN ELECTRICITY BOARD
Electricity House, Colston Avenue, Bristol.
SOUTHERN ELECTRICITY BOARD
Southern Electricity House, Littlewood Green, Maidenhead.
STELLA LAMP CO. LTD.
158-160, Shaftesbury Avenue, London, W.C.2.
STRAND ELECTRIC & ENGINEERING CO. LTD.
24, Floral Street, London, W.C.2.
STRETFORD, BOROUGH OF
Town Hall, Talbot Road, Stretford, Lancs.
STRONG ELECTRIC CORPORATION (GREAT BRITAIN) LTD.
Newbourne Works, Whyteleafe, Surrey.
SUPERCONCRETE PIPES (S.A.) LTD.
P.O. Box 92, Roodeport, Transvaal, South Africa.
SUPERIOR MANUFACTURING DEVELOPMENT CO. (PTY.) LTD.
P.O. Box 109, Bramley, Transvaal, S. Africa.

THERMO-PLASTICS LTD.
Luton Road Works, Dunstable, Beds.
THORN ELECTRICAL INDUSTRIES (S.A.) (PTY.) LTD.
P.O. Box 75, Industria, Johannesburg, South Africa.
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Thorlux Works, Welby Road, Hall Green, Birmingham, 28.
TROUGHTON & YOUNG LTD.
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TUCKER & EDGAR (TEEANEE LTD.)
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VERITY'S (MAXLUME) LTD.
Hazelwell Works, Fordhouse Lane, Stirchley, Birmingham, 30.

WALSALL CONDUITS LTD.
Excelsior Works, West Bromwich, Staffs.
WALTON (ELECTRICAL) LTD., J.
333, Chapel Street, Salford, Lancs.
WARDLE ENGINEERING CO. LTD.
Old Trafford, Manchester.
WEBBER & CO. LTD., J. M.
244, Tottenham Court Road, London, W.1.
WHITWORTH ELECTRIC LAMP CO. LTD.
6-12, Gorleston Street, London, W.14.
WOKINGHAM PLASTICS LTD.
Denton Road, Wokingham, Berks.
WRIGHT (ELECTRICAL) LTD., A. J.
67-69, Victoria Street, Liverpool, 1.

YORKSHIRE ELECTRICITY BOARD
Wetherby Road, Scarcroft, Thorner, Leeds.

Additions to the List of Members

Fellowship

The Council has accepted the following application for Fellowship of the Society :—

R. Croft

Diploma Membership

The Council has accepted applications for the Society's Diploma in Lighting Engineering from the following, who are now Diploma Members :—

J. R. Barker
R. T. H. Bird
R. A. Bullock
P. T. Hookway
A. C. Holden
N. Kwong
S. L. Lyons
E. G. Mara
K. H. Ragsdale
A. R. M. Spalding

New Members

The following applicants have been duly elected by the Council to Membership of the Society :—

Corporate Members

Bagnall, H. E.	22 Wheats Avenue, Harborne, Birmingham, 17.
Banfield, G. E.	17 Beech Drive, Knutsford, Cheshire.
Beck, J.	26 Cheviot Drive, Newton Mearns, Renfrewshire.
Beese, C. R.	"Two Stacks," St. Francis Road, Keynsham, Somerset.
Brady, D. H.	179 King's Road, Manchester, 16.
Butler, D. J.	282 Oldham Road, Royton Lancashire.
Butler, R. W.	66 10th Road, Kew, Johannesburg.
Cowlishaw, G. R.	25 Fairview Road, Woodthorpe, Nottingham.
Davies, I. F.	8 Causton Road, London, N.6.
Deacon, G. D.	30 Shelford Road, Radcliffe-on-Trent, Notts.
Drage, J. A.	P.O. Box 1070, Bulawayo.
Edson, T. W. B.	The Bungalow, Main Road, Plumtree, Notts.
Fry, F. H. R.	35 Lascelles Road, Slough, Bucks.
Goulden, W.	20 Ashdene Road, Heaton Mersey, Stockport.
Guha, S. K.	67 Gower Street, London, W.C.1.
Hammond, W. B.	The Spinney, Cuffley Hill, Goffs Oak, Herts.
Harborow, A. H.	148 Hatherton Road, Cannock, Staffs.
Harris, N.	P.O. Box 1626, Johannesburg.
Holt, G. G.	204 Minster Road, Minster, Isle of Sheppey, Kent.
Hooker, R. F.	246 Sirdar Road, Wood Green, London, N.22.
Howard, J. H.	Ferndene, 43 Louis Drive, Rayleigh, Essex.
Huntington, A.	177a Stanstead Road, Forest Hill, London, S.E.23.
Jackson, E.	22 Delabole Road, Merstham, Surrey.
Jones, B. F.	5103, Chesley Avenue, Los Angeles 43, California, U.S.A.
Leat, S.	124 Dobbin Hill, Sheffield, 11.
Loudon, A. M.	6 Hexham Gardens, Glasgow, S.1.
McGregor, J.	c/o Associated Elec. Industries Ltd., 127 George Street, Edinburgh.
Merriam, K. A.	"Richmond," Harston Road, Newton, Cambs.
Millman, W.	32 Pinfold Street, Howden, E. Yorks.
Milton, G. R.	6 Lanfine Road, Paisley.
Nisbet, R. W.	286 Kingsacre Road, Bankhead, Rutherglen, Lanarkshire.
Perry, E. A.	28c Afton Road, Cumbernauld, Dunbartonshire.
Planck, R. H.	15 Greenheys Drive, South Woodford, London, E.18.
Prieto, F.	Santiago Chile, c/o Gibbs and Co., Casilla, 67—D.
Prosser, K. J.	14 Jacobean Lane, Copt Heath, Knowle, Warks.
Ranson, G.	James A. Jobling & Co. Ltd., Wear Glass Works, Sunderland.
Reid, W. F.	39 Brackenbrae Road, Bishopbriggs, Via Glasgow.
Rice, N. R.	69 Sutherland Avenue, Leeds, 8, Yorkshire.
Richardson, J. B.	Philips Electrical Ltd., 1 Gerrard Place, London, W.1.
Scales, A. M.	Atlas Lighting Ltd., 9/15 Waverley Street, Glasgow, S.1.
Schofield, F.	10 All Saints Close, Royton, Lancs.
Smith, I.	"Vrondeg," Hillfoot Road, Woolton, Liverpool.
Speddy, W. E.	G.E.C. Ltd., 52/60 Corporation Road, Middlesbrough.
Stone, G. R.	62 Griffins Brook Lane, Bournville, Birmingham.
Subotich, Z.	21 Gailmort Place, Toronto 9, Canada.
Sutton, H. S.	29 South Park Crescent, Ilford, Essex.
Thomas, R. E.	73 Lincoln Road, Walsall, Staffs.
Thornton, R. V. G.	16 Kingfield Gardens, Woking, Surrey.
Ward, S.	P.O. Box 1191, Nairobi, Kenya,
Wiles, R. T.	53 Thornton Road, Heald Green, Cheshire.
Zimbler, L.	53 Upcroft Avenue, Edgware, Middlesex.

Student Members

Gandhi, C. N.	26 Thurlby Road, Wembley Road, Wembley, Middlesex.
Gorrod, P. J. B.	23 Canterbury Avenue, Sheffield, 10.
Hunt, C. A.	170 King's Road, Erdington, Birmingham.

Rigg, B.	Dept. of Electrical Engineering, The University, Mappin Street, Sheffield, 1.
Smith, I.	c/o Muir, 203 Copland Road, Glasgow, Lanarkshire.
Stimson, R. F.	74a London Road, Forest Hill, London, S.E.23.
Strawford, B. R.	17 Lon Mafon, Tycoch, Swansea.

Transfer from Student to Corporate Membership

Clements, L. A.	17 Queensdown Road, Clapton, London, E.5.
Hutchison, J. S.	306 Springburn Road, Glasgow, N.1.
Leishman, J. S.	9 Gordon Terrace, Falkirk, Stirlingshire.
Skinner, P. L.	9 Dale View Crescent, Chingford, London, E.4.

Annual General Meeting

Notice is hereby given that the Annual General Meeting of The Illuminating Engineering Society will be held at 4.30 p.m. on Monday, May 16, 1960, at the Royal Hall, Harrogate, at which the following business will be brought before the meeting :—

1. To receive the Report of the Council and the Accounts for the year ending December 31, 1959.
2. To elect Officers and Members of the Council.
3. To fix the remuneration of the Auditors.

U.D.C. 628.93

Utilisation Factors for Indirect and Horizontal Components

By RONALD CROFT, B.Sc., A.M.I.E.E., A.M.I.H.V.E. (*Fellow*)

Since Moon and Spencer produced their Interreflection Data there has been dissatisfaction with the Harrison and Anderson utilisation factors. This was not fully overcome by the Jones-Neidhart Method because of the considerable work involved. Mr. Simons deserves the congratulations of the entire lighting world for taking us out of the doldrums with the valuable and extensive three curve data based on interreflection theory as presented in his recent paper (Transactions, Volume 24, No. 4, page 153, 1959).

Many, like the writer, may have a lot of luminaires analysed on the old three curve basis with a sine horizontal component, and for this and other reasons, regret the change to the uniform radial component. So for those who prefer it, the following data for the Harrison and Anderson horizontal and indirect components are presented to be used in conjunction with Mr. Simons' tables of extended classifications of direct utilisation factors. They were obtained from the Jones-Neidhart data with very little extrapolation in a few cases. At worst it was necessary to extend a graph by a direct ratio of 0.016, i.e. about 2 per cent of the range of the graph, so there was definitely no loss of accuracy. The third figure is given, but naturally because of the scale of the graphs it cannot always be guaranteed.

UTILISATION FACTORS FOR INDIRECT (COSINE) AND HORIZONTAL (SINE) COMPONENTS FROM ZONAL-INTERFLECTANCE DATA

FLOOR REFLECTANCE 10%, SPACING RATIO 1.0

Table IA

Indirect Component—Suspended (S.S.R. = 2.0)

Ceiling Reflectance %		75			50			30		0	Ceiling Ratio
Wall Reflectance %		50	30	10	50	30	10	30	10	0	
Room Ratio	Room Index										
.6	A	.161	.099	.062	.115	.072	.041	.052	.027	0	.591
.8	B	.224	.154	.107	.156	.107	.073	.072	.046	0	.659
1.0	C	.284	.209	.157	.195	.145	.106	.091	.065	0	.711
1.25	D	.348	.270	.215	.235	.183	.143	.112	.086	0	.757
1.5	E	.401	.322	.264	.264	.212	.175	.128	.104	0	.790
2.0	F	.482	.403	.344	.315	.266	.227	.155	.136	0	.836
2.5	G	.530	.462	.403	.349	.303	.265	.176	.158	0	.868
3.0	H	.570	.507	.450	.373	.332	.299	.192	.175	0	.887
4.0	I	.623	.571	.519	.407	.371	.343	.215	.204	0	.913
5.0	J	.656	.612	.565	.426	.398	.371	.228	.219	0	.932
∞	—	.811	.811	.811	.526	.526	.526	.309	.309	0	1.0

Table IB

Indirect Component—Ceiling Mounted

Ceiling Reflectance %		75			50			30		0	Ceiling Ratio
Wall Reflectance %		50	30	10	50	30	10	30	10	0	
Room Ratio	Room Index										
.6	A	.249	.179	.127	.159	.119	.079	.074	.050	0	.840
.8	B	.330	.258	.208	.219	.173	.134	.099	.079	0	.880
1.0	C	.395	.324	.272	.262	.216	.178	.123	.098	0	.900
1.25	D	.463	.390	.337	.301	.256	.222	.138	.118	0	.920
1.5	E	.511	.444	.388	.333	.288	.256	.152	.132	0	.940
2.0	F	.575	.518	.468	.368	.333	.306	.168	.148	0	.960
2.5	G	.617	.565	.522	.396	.366	.340	.186	.166	0	.980
3.0	H	.646	.605	.558	.412	.387	.362	.198	.180	0	.990
4.0	I	.684	.654	.608	.436	.416	.387	.210	.189	0	.990
5.0	J	.711	.684	.646	.446	.430	.416	.225	.205	0	1.000
∞	—	.811	.811	.811	.526	.526	.526	.309	.309	0	1.000

Table IIA

Horizontal Component—Suspended (S.S.R. = 2.0)

.6	A	.178	.110	.069	.162	.104	.062	.100	.057	.042	.128
.8	B	.239	.164	.111	.213	.150	.102	.138	.095	.070	.165
1.0	C	.296	.213	.154	.259	.191	.137	.172	.124	.092	.198
1.25	D	.361	.270	.205	.310	.237	.182	.210	.163	.121	.229
1.5	E	.413	.319	.250	.350	.277	.220	.243	.194	.145	.254
2.0	F	.493	.402	.330	.414	.343	.284	.295	.250	.185	.296
2.5	G	.553	.465	.393	463	.394	.338	.336	.293	.216	.327
3.0	H	.600	.518	.447	.500	.436	.383	.371	.329	.242	.351
4.0	I	.666	.593	.526	.554	.496	.449	.421	.386	.283	.378
5.0	J	.705	.641	.579	.584	.535	.490	.450	.418	.307	.399
∞	—	.946	.946	.946	.789	.789	.789	.670	.760	.500	.500

Table IIB

Horizontal Component—Ceiling Mounted

.6	A	.245	.171	.116	.193	.139	.090	.114	.076	.042	.420
.8	B	.326	.244	.187	.262	.199	.149	.158	.120	.070	.440
1.0	C	.390	.305	.243	.312	.246	.195	.195	.153	.092	.450
1.25	D	.459	.372	.306	.363	.297	.247	.233	.193	.121	.460
1.5	E	.510	.425	.358	.405	.339	.289	.264	.225	.145	.470
2.0	F	.582	.505	.440	.460	.403	.355	.313	.272	.185	.480
2.5	G	.635	.564	.501	.505	.450	.405	.352	.314	.216	.490
3.0	H	.674	.609	.547	.537	.487	.443	.383	.347	.242	.495
4.0	I	.728	.673	.614	.583	.541	.498	.428	.393	.283	.495
5.0	J	.762	.712	.660	.608	.570	.536	.457	.425	.307	.500
∞	—	.946	.946	.946	.789	.789	.789	.670	.670	.500	.500

NOTES: (1) Ceiling ratios and 0-0 factors for horizontal component must be doubled for use with Jones-Neidhart ceiling and wall illumination data. (2) For direct utilisation factors see Simons, Trans. Illum. Eng. Soc. (London), **24,** 4 (1959). (3) S.S.R. = Spacing suspension ratio.

Election of Officers and Council

Session 1960-1961

In accordance with the procedure specified in the Articles of the Society, a list of existing Officers and Members of Council, of vacancies occurring and of duly qualified persons nominated by the Council for vacancies about to occur in the offices of President, Vice-Presidents, Hon. Treasurer, Hon. Secretary, Hon. Editor of Transactions, and Ordinary Members of Council, is presented below for the information of the Members of the Society. In the event of any Members desiring to put forward other names, the Council will be pleased to receive such nominations, which should be made in accordance with the following rule (Article 47) : "After the issue of the Council's list, and not later than the 15*th day of April* next following, any ten Members (but no more than ten) may nominate any other duly qualified person to fill any such vacancy by delivering such nomination in writing to the Hon. Secretary, together with the written consent of such person to accept office if elected, but each such nominator shall be debarred from nominating any other person for the same office at such election."

Present Officers and Members of Council

PRESIDENT : *H. G. Campbell.*

PAST PRESIDENTS : J. W. T. Walsh, The Rt. Hon. the Earl of Mount Edgcumbe, A. W. Beuttell, A. Cunnington, S. English, F. C. Smith, W. J. Jones, H. Buckley, E. Stroud, H. C. Weston, J. M. Waldram, J. N. Aldington, L. J. Davies, J. G. Holmes, W. J. Wellwood Ferguson, W. R. Stevens, E. C. Lennox, A. G. Higgins, W. E. Harper, E. B. Sawyer, C. C. Smith.

VICE-PRESIDENTS : *F. A. Benson, A. H. Olson, W. E. Rawson-Bottom, W. S. Stiles, D. L. Tabraham.*

MEMBERS OF COUNCIL : *A. E. Bird* (1957), B. M. Cobbe (1959), *J. B. Collins* (1957), *P. H. Collins* (1957), J. G. Christopher (1959), *C. Dykes Brown* (1957), E. S. Evans (1958), *A. E. Gaster* (1957), J. T. Grundy (1958), J. W. Howell (1959), C. A. Padgham (1958), A. O. Johnson (1959), J. S. McCulloch (1959), A. H. Nash (1959), *A. G. Penny* (1957), A. Roberts (1958), T. Roberts (1958), H. R. Ruff (1959), *W. Imrie-Smith* (1957), W. T. Souter (1958), D. A. Strachan (1958), J. W. Strange (1958), R. L. C. Tate (1959), *A. Wilcock* (1957).

REPRESENTATIVES OF CENTRES (*ex-officio*) : J. H. Munns (Bath & Bristol), J. R. Yeates (Birmingham), A. J. Dalton (Cardiff), G. R. N. Chalmers (Edinburgh), J. Stewart (Glasgow), T. H. Bradley (Kingston upon Hull), A. J. Johnson (Leeds), E. W. Freeman (Leicester), W. J. Forster (Liverpool), E. J. Smith (Manchester), B. Wray (Newcastle), D. R. M. Hornsey (Nottingham), V. Loupart (Sheffield), H. L. Roston (South Africa).

HON. TREASURER : *A. W. Gostt* (1959). HON. SECRETARY : *W. E. Harper* (1959). HON. EDITOR OF TRANSACTIONS : *H. Hewitt* (1959).

The names in italics are those of Officers or Members retiring in 1960. The date in parentheses after each name indicates the date of election to Office or Membership of the Council.

Nominated by the Council to fill vacancies :

PRESIDENT : W. S. Stiles.

VICE-PRESIDENTS : H. H. Ballin, F. A. Benson, W. E. Rawson-Bottom, W. T. Souter, A. H. Young.

MEMBERS OF COUNCIL : N. Boydell (Souther Eastern Electricity Board), H. Carpenter (County Borough of Blackpool), A. J. Dalton (South Wales Electricity Board), D. W. Durrant (General Electric Co. Ltd.), P. Petherbridge (D.S.I.R., Building Research Station), A. Pott (Ministry of Education), W. Robinson (British Electrical Development Association), A. W. S. Tarrant (Battersea College of Technology).

REPRESENTATIVES OF CENTRES (*ex-officio*). (To be appointed before October 1, 1960.)

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